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The biogeography and ecology of common diatom species in the northern North Atlantic, and their implications for paleoceanographic reconstructions

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Keywords: Diatoms, calibration dataset, Northern Hemisphere, sea surface temperature, sea ice

Abstract

Sound knowledge of present-day diatom species and their environments is crucial when attempting to reconstruct past climate and environmental changes based on fossil assemblages. For the North Atlantic region, the biogeography and ecology of many diatom taxa that are used as indicator-species in paleoceanographic studies are still not well known. Using information contained in large diatom-environment calibration datasets can greatly increase our knowledge on diatom taxa and improve the accuracy of paleoenvironmental reconstructions. A diatom calibration dataset including 183 surface sediment samples from the northern North Atlantic was used to explore the distribution and ecology of 21 common Northern Hemisphere diatom taxa. We define the ecological responses of these species to April sea ice concentrations and August sea surface temperatures (aSSTs) using Huisman-Olff-Fresco (HOF)-response curves, provide distribution maps, temperature optima and ranges, and high-quality light microscope images. Based on the results, we find species clearly associated with cold, warm and temperate waters. All species have a statistically significant relationship with aSST, and 15 species with sea ice. Of these, *Actinocyclus curvatulus*, *Fragilariopsis oceanica* and *Porosira glacialis* are most abundant at high sea ice concentrations, whereas *Coscinodiscus radiatus*, *Shionodiscus oestrupii*, *Thalassionema nitzschioides*, *Thalassiosira angulata*, *Thalassiosira nordenskiöldii* and *Thalassiosira pacifica* are associated with low sea ice concentrations/ice-free conditions. Interestingly, some species frequently used as sea ice indicators, such as *Fragilariopsis cylindrus*, show similar abundances at high and low sea ice concentrations with no statistically significant relationship to sea ice.

Introduction

The need to better understand the impacts of the ongoing global warming imposes a demand for paleoclimate records extending well beyond the instrumental era. These records can help us understand

interactions between different components of the climate system and improve climate model projections of future impacts of climate warming. Paleoclimate research can help define baselines of natural climate change, thus helping us to set the recent observed changes in the long-term natural climate context. The demand for paleoclimate records is especially crucial in the Arctic region because of the amplified polar warming (e.g., Pithan and Mauritzen, 2014) and associated loss of Arctic sea ice during the last decades (Parkinson and Cavalieri, 2008; Parkinson, 2014; Kwok and Cunningham, 2015). Sea surface temperatures (SSTs) and sea ice concentrations are important parameters in northern high latitude paleoceanographic research, as SSTs strongly influence the Arctic sea ice extent, the stability of the Greenland Ice Sheet and climate of the northwest Europe (Holland et al., 2008; Årthun et al., 2016), whereas Arctic sea ice is a critical component of the climate system via regulating heat and moisture exchange between the ocean and the atmosphere, and via surface albedo feedbacks.

Marine fossil diatom assemblages are a widely used proxy for producing paleoceanographic and paleoclimatic records. Diatoms have a strong relationship to surface water hydrography and thus are excellent indicators of ocean surface conditions and variability of water masses. Diatoms are diverse and abundant at high latitudes and today, a large number of studies exist from various parts of the northern North Atlantic region: the Nordic Seas (Koç Karpuz and Schrader, 1990; Koç and Jansen, 1994; Miettinen et al., 2012), around Iceland (Jiang et al., 2001; 2002; 2005; 2015; Witak et al., 2005; Miettinen et al., 2011; Xiao et al., 2017), northern Svalbard (Koç et al., 2002; Oksman et al., 2017a), around Greenland (Andersen et al., 2004a; 2004b; Berner et al., 2008; 2011; Justwan et al., 2008; Justwan and Koç, 2009; Ren et al., 2009; Miettinen et al., 2015), Baffin Bay (Williams, 1986; 1990; 1993; Krawczyk et al., 2010; 2014; 2016; Sha et al., 2014; 2016; 2017; Oksman et al. 2017b) and the Labrador Sea (De Sève, 1999; Weckström et al., 2013; Pearce et al., 2014a). Some diatom species are associated with sea ice and this link has been used to reconstruct past sea ice variability (Justwan and Koç, 2008; Sha et al., 2014; 2016; 2017; Miettinen et al., 2015; Krawczyk et al., 2016). The earliest diatom-based reconstructions were conducted using qualitative diatom assemblage data (e.g., Williams, 1993; Witak et al., 2005; Krawczyk et al., 2010), but in the past few decades, the use (as well as the number) of calibration datasets, consisting of surface sediment diatom assemblages and associated measured environmental data for quantitative reconstructions of SST and sea ice, has increased remarkably (Koç Karpuz and Schrader, 1990; Jiang et al., 2001; 2005; Andersen et al., 2004a; Justwan and Koç, 2008; Sha et al., 2014; Miettinen et al., 2015; Krawczyk et al., 2016).

Although diatom calibration datasets have been used to reconstruct paleoceanographic and paleoclimate variability, the biogeography and especially the ecology of the common (key) taxa (i.e., the relations of these species to one another and to their environment) have largely remained undescribed, and literature on diatom ecology in the North Atlantic region is scarce (e.g., von Quillfeldt, 2000; 2001; Jiang et al., 2001; Andersen et al., 2004b; Pearce et al., 2014b; Krawczyk et al., 2014; 2016). Understanding the ecology and living environment of these indicator species is essential given the frequent use of diatom assemblage analysis in both quantitative and qualitative paleoceanographic reconstructions. The extensive spatial coverage and the large number of sites make large calibration datasets not only an excellent tool for paleoclimate reconstructions but provide also a highly useful platform for studying the ecology and biogeography of diatom taxa. This paper presents the most common diatom taxa in the northern North Atlantic calibration dataset and assesses their responses to the paleoclimatically important environmental parameters August SST (aSST) and April sea ice concentrations (aSIC). August and April have been found to be statistically the most significant months in explaining diatom assemblage distribution along SST and SIC gradients (Berner et al., 2008; Miettinen et al., 2015), thus aSST and aSIC are the most commonly used parameters in quantitative diatom-based paleoceanographic reconstruction. The aim of this study is to (1)

present the geographical distribution of the common diatom species in the northern North Atlantic, (2) discuss the relationship between diatom species and two important environmental variables (SST and sea ice) and (3) present good-quality light-microscopy images of these species to aid with species identification.

Materials and methods

A diatom calibration dataset (Andersen et al., 2004a, 2004b; Miettinen et al., 2015) including 183 surface sediment samples (prepared for analysis using standard methodology, see Koç Karpuz and Schrader, 1990; Koç et al., 1993) and measured environmental data (SSTs and sea ice concentrations) around the North Atlantic, the Labrador Sea, the Nordic Seas and Baffin Bay (Fig. 1) was used in this study to examine the biogeography and ecology of common North Atlantic diatom taxa. The calibration dataset consists of 52 diatom species in total, of which we selected the 21 most common species based on their wide-ranging occurrence at high latitudes and their frequent use as paleoceanographic indicators in the northern North Atlantic and Arctic regions. However, some common North Atlantic taxa, such as *Chaetoceros* resting spores, *Paralia sulcata*, *Fossula arctica* and *Fragilariopsis reginae-jahniae* were not included in this study. *Chaetoceros* resting spores were not included in the dataset as they consist of several species with potentially different ecologies and they have shown negligible sensitivity to SST (Koç Karpuz and Schrader, 1990). *Paralia sulcata* was part of the original version of the calibration dataset (Koç Karpuz and Schrader, 1990), but was found to have too broad a temperature tolerance and was thus removed from the dataset by Andersen et al. (2004a). *Fossula arctica* and *Fragilariopsis reginae-jahniae* are sea-ice associated species which have only relatively recently been described (in 1996 and 2000, respectively) and were not included in the original calibration dataset. Hence, these species are not presented here as separate taxa but were, however, likely included in the total counts of *Fragilariopsis oceanica* (see discussion under individual species).

The 183 surface sediment samples in the calibration dataset cover the main areas of the North Atlantic between 42°N and 79°N (Fig. 1). The surface sediment samples were taken during multiple cruises from various water depths using either a box-corer or a multicorer. The sample location, sampling year, water depth and modern August SST and April sea ice data are compiled into Appendix 1. Every surface sediment sample represents the uppermost 1 cm of the sediment, and all the samples were visually verified to represent the topmost sediment layer. The majority of the samples (80) were collected before the 1990s and were part of the original calibration dataset by Koç Karpuz and Schrader (1990). Later, 57 samples, collected between the years 1990–2000, were added by Birks and Koç (2002) and 46 samples, collected between 2006–2008, were added by Miettinen et al. (2015). Diatom concentrations (10^6 valves/g dry sediment) for the first 137 samples are presented in Koç Karpuz and Schrader (1990) and Birks (2001), whereas for the remaining 46 samples concentrations have not been analyzed.

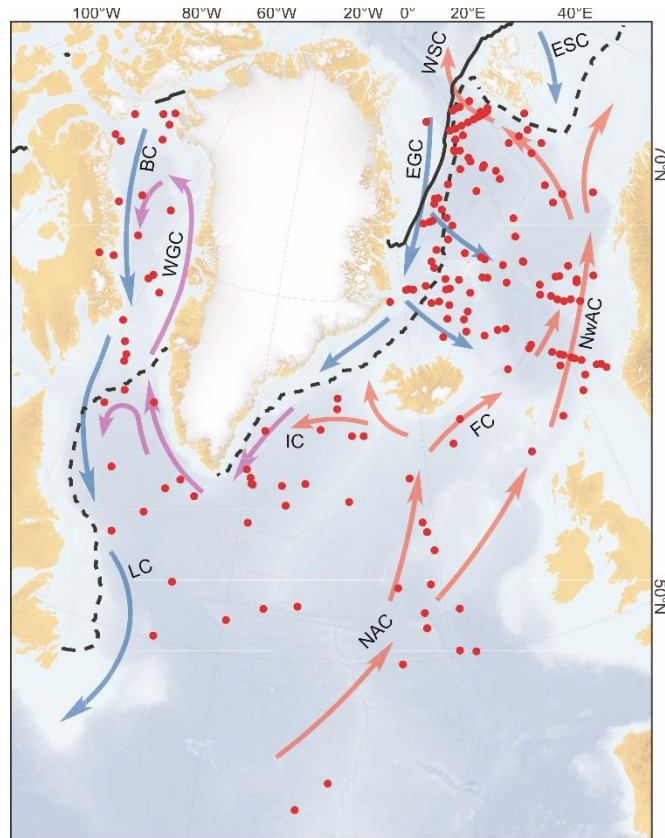


Figure 1. Map of the northern North Atlantic showing locations of the 183 surface sediment samples in the North Atlantic diatom calibration dataset, the main surface ocean currents and sea ice extent. Median sea ice extent over the years 1981-2010: winter maximum (March) is shown as a dashed line and summer minimum (September) as a full line (Fetterer et al., 2017). Warm ocean currents are presented with red arrows, cold currents with blue arrows and temperate water currents with purple arrows. NAC=North Atlantic Current, NwAC=Norwegian Atlantic Current, FC=Faroes Current, ESC= East Spitsbergen Current, WSC=West Spitsbergen Current, EGC= East Greenland Current, IC=Irminger Current, WGC=West Greenland Current, BC=Baffin Current, LC=Labrador Current.

The modern environmental data associated with each surface sediment sample was gathered from the World Ocean Atlas 2001 for August SSTs, including all observations since the year 1900 (Stephens et al., 2002). Satellite data for the modern April sea ice data was compiled from the National Snow and Ice Data Center (NSIDC, www.nsidc.com; Cavalieri et al. 1996) using data between years 1979-1999 for samples collected before 2000, and years 1979-2006, 1979-2007 and 1979-2008 for the samples taken in 2006, 2007 and 2008, respectively (Miettinen et al., 2015).

The temperature ranges of each species are based on the occurrence of the species in the surface sample dataset. The surface sample associated with the coldest modern temperature of the dataset, which includes a given species determines the minimum temperature for this species. Correspondingly, the sample associated with the warmest measured SST defines the warmest temperature for the species. Note that the temperature range of the data set is 0–20°C. The temperature optimum for each species was calculated from the dataset using the weighted averaging method (WA, ter Braak and Looman, 1986). We would like to emphasize that species' optima are always defined by the temperature range of the calibration dataset and should not be taken as absolute values. The distribution maps are based on the relative abundance of the species in the surface sediment samples (percentage of diatom valves based on total counted valves (minimum of 300 valves). The counted valves in the dataset include the 52 species which were found to have

152 a statistically significant response to temperature (Koç Karpuz and Schrader, 1990; Birks and Koç, 2002;
153 Andersen et al., 2004b).

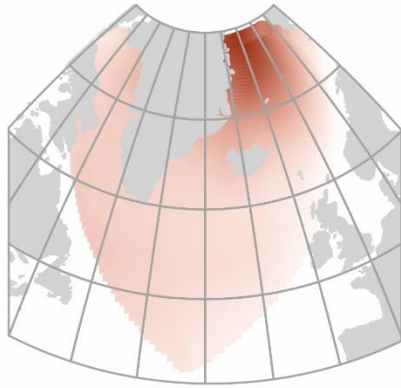
154

155 The type and significance of the response of each taxon to SST and sea ice concentration was assessed by
156 fitting a series of Huisman-Olff-Fresco (HOF) hierarchical response models (Huisman et al., 1993) following
157 Jansen and Oksanen (2013). This procedure fits seven models of increasing complexity, from a null model or
158 flat response (i.e., no relationship, model I), through monotone sigmoid (II), monotone sigmoid with plateau
159 (III), unimodal symmetric (IV), unimodal skewed (V), bimodal with equal peaks (VI) and bimodal with unequal
160 peaks (VII), and selects the most parsimonious model using Akaike information criterion corrected for small
161 sample size (AICc) and a bootstrap approach (500 permutations) to ensure model stability. Taxa are deemed
162 to have a statistically significant relationship to either SST or sea ice concentration if the selected response
163 yields statistically significant improvement in fit over a null or flat model. All numerical analyses were
164 performed using the R 3.4.1 software for statistical computing (R Core Team, 2017) with the package eHOF
165 (Jansen and Oksanen, 2013).

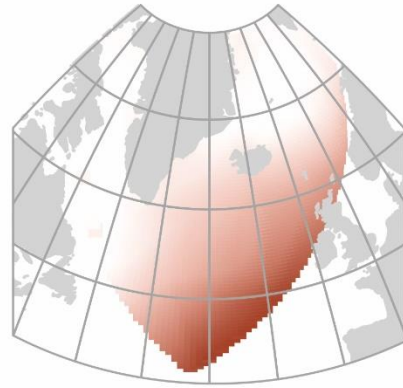
166

167 Q-mode factor analysis (Imbrie and Kipp, 1971) was applied to the surface sediment diatom data to
168 investigate the distribution of distinct diatom assemblages in the surface sediment dataset. This analysis has
169 been applied to the earlier version of this calibration dataset (Koç Karpuz and Schrader, 1990; Andersen et
170 al., 2004b), and shows the distribution of eight factors (composition of diatom assemblages related to distinct
171 water masses): Greenland Arctic Waters, North Atlantic Current, Sub-Arctic Waters, Norwegian Atlantic
172 Current, Marginal Ice Zone (renamed from Sea Ice assemblage in Oksman et al. 2017b), Arctic Waters, East-
173 West Greenland Current and Mixed Water Masses (Fig. 2).

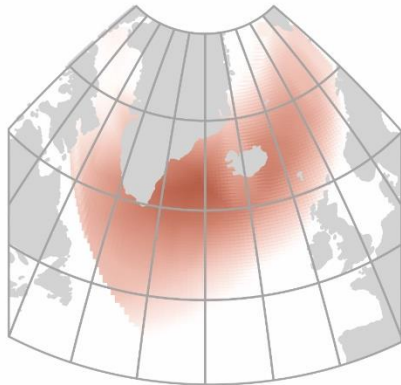
Greenland Arctic Waters



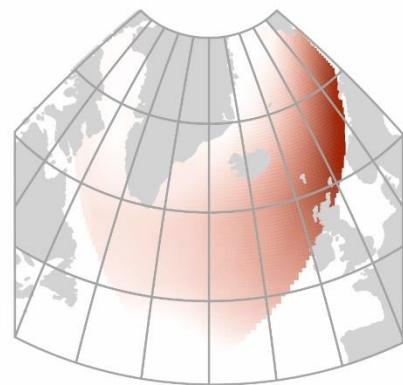
North Atlantic Current



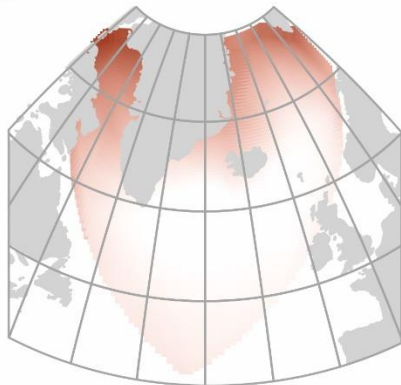
Sub-Arctic Waters



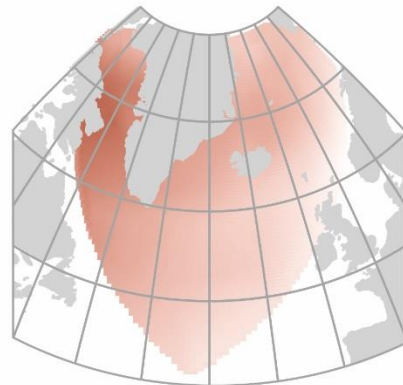
Norwegian Atlantic Current



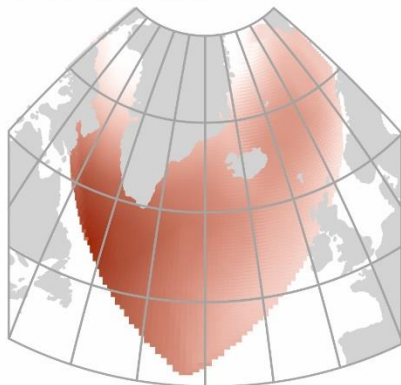
Marginal Ice Zone



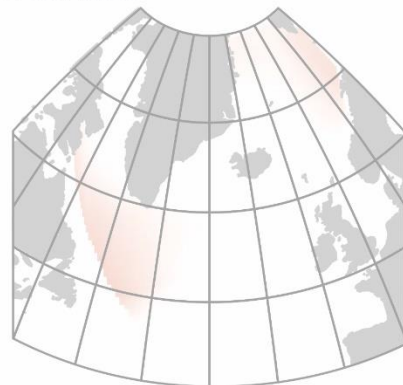
Arctic Waters



East-West Greenland Current



Mixed Water Masses



174
175 Figure 2. Geographical distribution of the eight factor assemblages discussed in the individual species descriptions
176 (Greenland Arctic Waters, North Atlantic Current, Sub-Arctic Waters, Norwegian Atlantic Current, Marginal Ice Zone,
177 Arctic Waters, East-West Greenland Current and Mixed Water Masses) frequently referred to in the text. The
178 distribution of each factor assemblage is represented in red, i.e., stronger red shading referring to higher loadings of

179 the factor assemblage. These factors are the same as in Andersen et al. (2004b) but are based on an extended number
180 of surface sediment samples compared to Andersen et al. (2004b).

181

182

183 Photomicrographs of diatom species were taken using diatom microscope slides prepared from the
184 downcore sediment samples (core MD99-2322 from southeast Greenland, core SL-170 from Baffin Bay and
185 core AI07-14G from southeast Newfoundland) using a Zeiss AxioImager.M2 upright light microscope with
186 1000x magnification and an AxioCam MRc5 digital camera. Diatom slides were prepared according to Koç
187 Karpuz and Schrader (1990) and mounted with Naphrax that has a refractive index of 1.73. The given key
188 taxonomic literature is based on references that are widely used and easily available.

189

190

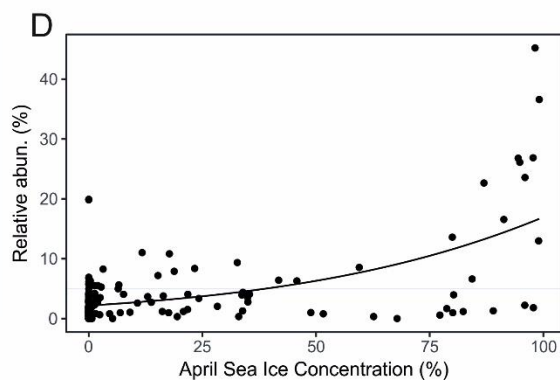
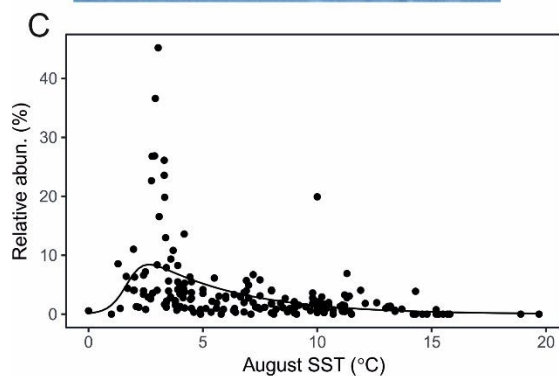
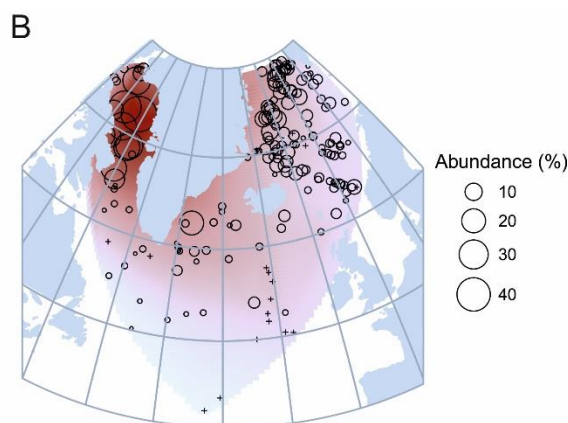
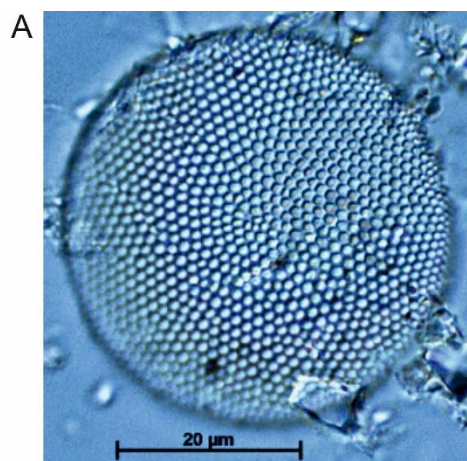
191 Results

192 The diatom taxa presented here include species from 10 different genera, the most common of which is
193 *Thalassiosira* with 9 species. Other common genera are *Coscinodiscus*, *Fragilariopsis* and *Rhizosolenia*. The
194 most common species in the calibration dataset are *Thalassiosira* *gravida*, *Thalassiothrix* *longissima*,
195 *Rhizosolenia* *hebetata* f. *semispina*, *Actinocyclus* *curvatulus*, *Thalassiosira* *antarctica* var. *borealis* resting
196 spore and *Shionodiscus* *trifultus*, which were present in more than 85% of the surface samples. Species that
197 generally were found at high abundances were *Thalassiosira* *gravida*, *Rhizosolenia* *hebetata* f. *semispina*,
198 *Thalassiosira* *antarctica* var. *borealis* resting spore and *Fragilariopsis* *oceanica* (abundances on average
199 between 8 and 14 %). The geographical distribution, temperature range, August SST optima and ecological
200 response curves to August SSTs and April sea ice concentrations of the diatom taxa are listed below and
201 summarized in Table 1. Diatom species are presented with their basionym and synonyms, light-microscopy
202 images and references to easily accessible key literature.

203

204 Table 1. aSST optimum, minimum and maximum, and response model types (I) a null model or flat response (i.e.,
205 no relationship), (II) through monotone sigmoid, (III) monotone sigmoid with plateau, (IV) unimodal
206 symmetric, (V) unimodal skewed, (VI) bimodal with equal peaks and (VII) bimodal with unequal peaks to aSST
207 (°C) and April sea ice for the 21 studied diatom taxa.

Species	SST optimum	min. SST	max. SST	Response to SIC	Response model type	
					SST	SIC
<i>Actinocyclus curvatulus</i>	4.7	0	15.2	Yes	V	II
<i>Bacterosira bathyomphala</i> spore	4.6	1	13.2	No	IV	I
<i>Coscinodiscus marginatus</i>	7.1	1.6	15.7	No	IV	I
<i>Coscinodiscus oculus-iridis</i>	6.1	1.7	14.4	Yes	IV	VII
<i>Coscinodiscus radiatus</i>	10.0	1.6	19.7	Yes	IV	II
<i>Fragilariopsis cylindrus</i>	4.4	0	13.2	No	IV	I
<i>Fragilariopsis oceanica</i>	3.6	0	13.1	Yes	II	V
<i>Porosira glacialis</i>	4.3	0	13.4	Yes	V	V
<i>Rhizosolenia hebetata</i> f. <i>hebetata</i>	5.1	1.3	15.2	No	IV	I
<i>Rhizosolenia hebetata</i> f. <i>semispina</i>	8.5	1.3	18.9	Yes	IV	II
<i>Shionodiscus oestrupii</i>	13.4	2.8	19.7	Yes	III	II
<i>Shionodiscus trifultus</i>	4.4	2.5	15.2	No	V	I
<i>Thalassionema nitzschioides</i>	11.1	1.3	19.7	Yes	V	II
<i>Thalassiosira angulata</i>	9.1	2.0	15.5	Yes	IV	VII
<i>Thalassiosira anguste-lineata</i>	4.0	0	15.5	Yes	V	V
<i>Thalassiosira antarctica</i> var. <i>borealis</i> spore	4.9	0	19.7	No	IV	I
<i>Thalassiosira gravida</i>	7.1	0	18.9	Yes	IV	II
<i>Thalassiosira hyalina</i>	4.7	0	11.9	Yes	IV	VII
<i>Thalassiosira nordenskiöldii</i>	7.1	1	13.2	Yes	V	II
<i>Thalassiosira pacifica</i>	9.0	2.4	13.2	Yes	IV	II
<i>Thalassiothrix longissima</i>	8.6	1	19.7	Yes	IV	II



216 Figure 3. *Actinocyclus curvatulus*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b)
217 Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location
218 with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

219

220 *Actinocyclus curvatulus* Janisch in A. Schmidt (Fig. 3)

221 Synonyms. *Coscinodiscus curvatulus* var. *subocellatus* Grunow, *Actinocyclus subocellatus* (Grunow) Rattray.

222 References. Hasle and Syvertsen, 1996, p. 121, pl. 19; Sancetta, 1982, p. 222, pl. 1, figs. 1–3; Jensen, 2003, p.
223 110, pl. 1, figs. 4–7; Scott and Thomas, 2005, p. 52, figs. 2.23a-d; Pearce et al., 2014b, p. 444, fig. 4.

224 Response to environmental gradients. Statistically significant relationship to both SST and sea ice.
225 Temperature range from 0 to 15.2°C, optimum 4.7°C. Highest abundances are found when sea ice
226 concentrations are above 80% (Fig. 3d).

227 Distribution. In the North Atlantic, *Actinocyclus curvatulus* is most abundant (>40% of total assemblages) in
228 the Baffin Bay and Nares Strait region (north of 65°N), however, it also occurs at relatively high abundances
229 (>30% of total assemblages) in the Nordic Seas and Fram Strait. The species is rare south of 60°N.

230 *Actinocyclus curvatulus* is described as a cold, bipolar species found from both Arctic and Antarctic waters
231 (Hasle and Syvertsen, 1996). It is an important contributor to the Arctic Water assemblage (Fig. 2; Andersen
232 et al., 2004b) as it occurs at high abundances under the East Iceland Current and the Jan Mayen Polar Current
233 and along the Sub-Arctic front (Fig. 2; De Sève, 1999; Jiang et al., 2001; Andersen et al., 2004b), yet the highest
234 abundances of *Actinocyclus curvatulus* in the calibration dataset are found in Baffin Bay (Fig. 3b). The species
235 can be defined as a “low SST – high sea ice concentration” indicator (Fig. 3c, d). Based on modern
236 observational data, *Actinocyclus curvatulus* is a marginal ice zone (MIZ) species, blooming in the cold and
237 fresher meltwater layer near the sea ice margin (von Quillfeldt et al., 2003). In Baffin Bay, *Actinocyclus*
238 *curvatulus* has been (together with *Shionodiscus trifultus*) grouped into the “Summer Pack Ice” assemblage,
239 representing heavy summer pack ice and also possibly indicating the Arctic/subarctic oceanographic
240 boundary (Williams, 1986; 1990).

241

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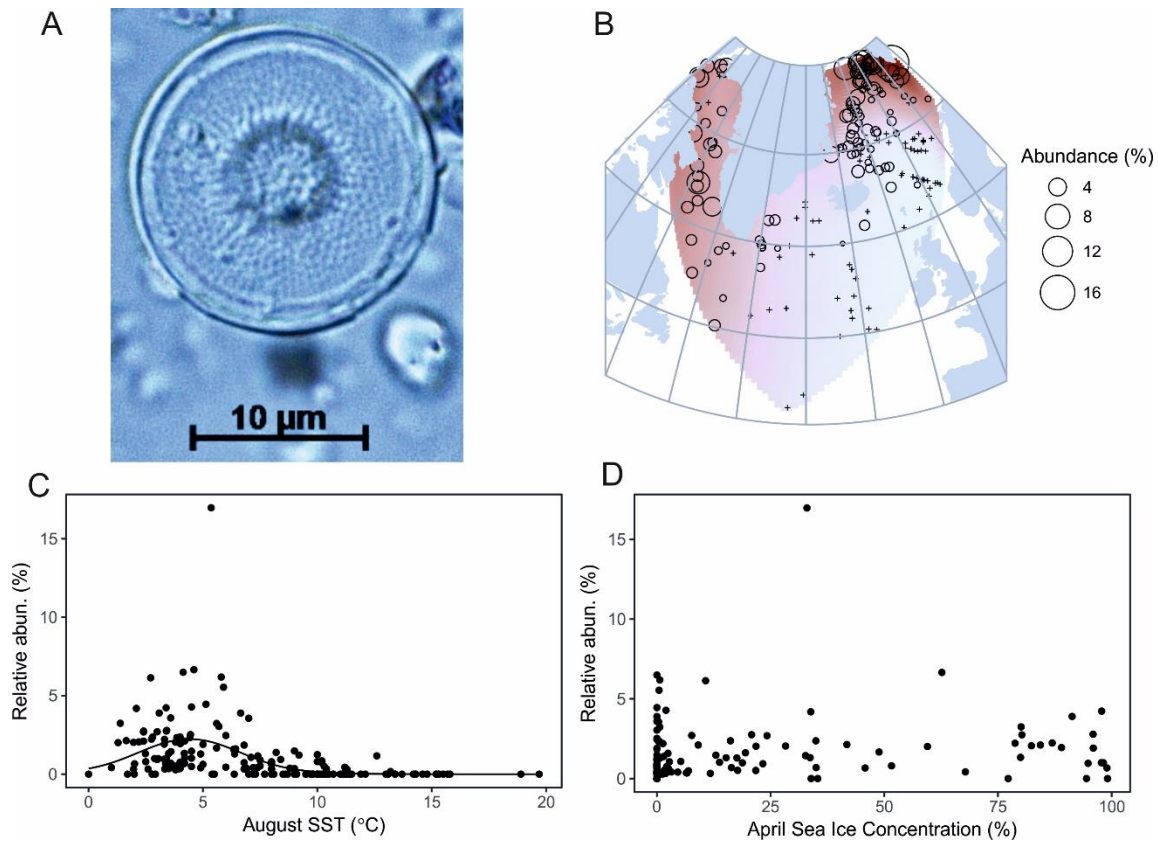


Figure 4. *Bacterosira bathyomphala* spore. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b) Geographical distribution (dark red shading indicates where abundances are highest, and the symbol + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

Bacterosira bathyomphala spore (Fig. 4)

Basionym. *Coscinodiscus bathyomphalus* Cleve.

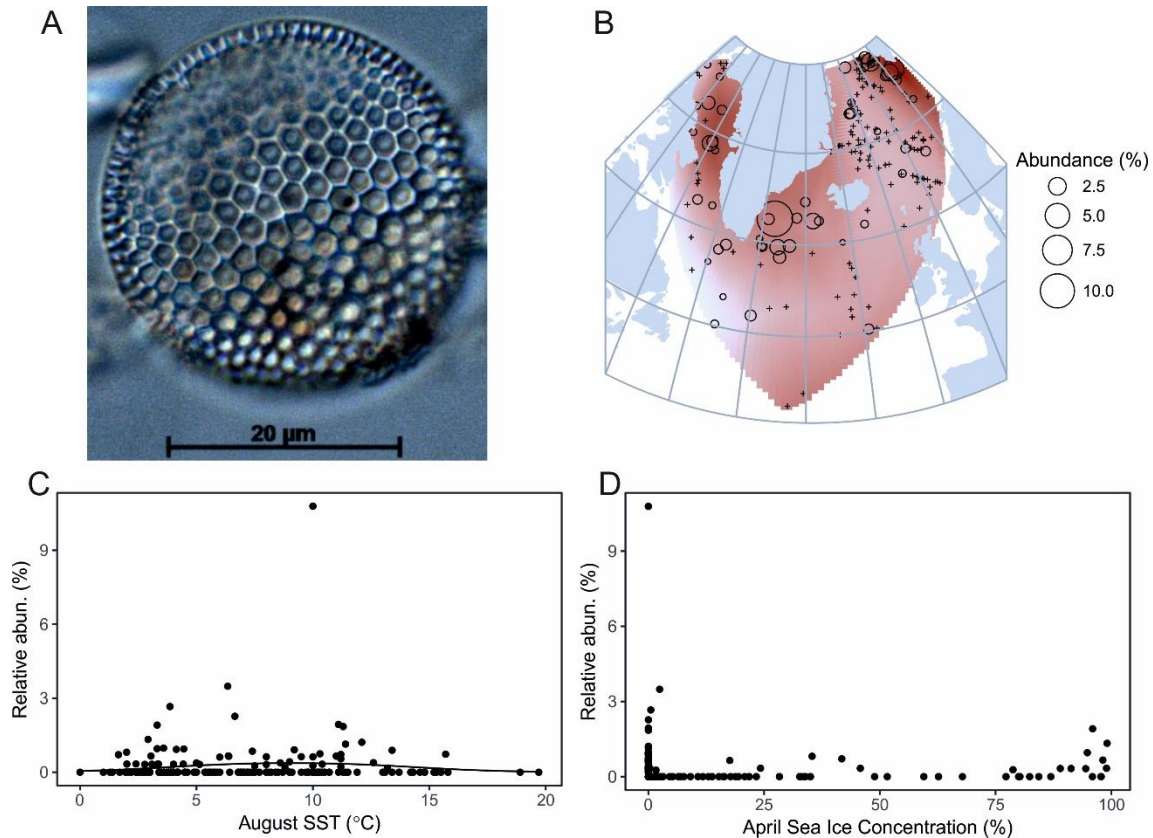
Synonyms. *Lauderia fragilis* Gran; *Bacterosira fragilis* (Gran) Gran.

References. Sancetta, 1982, p. 227, pl. 2, figs 1–4; Hasle and Syvertsen, 1996, p. 31, pl. 1; Cremer, 1998, p. 15, pl. 3, figs. 4–5; Bérard-Therriault et al., 1999, p. 18, pl. 1, figs a-c; Jensen, 2003, p. 112, pl. 2, figs. 3–5; Pienitz et al., 2003, p.23, pl. 6, fig. 14; Pearce et al., 2014b, p. 444, figs. 5–8.

Response to environmental gradients. Statistically significant relationship to SST, but not to sea ice. Temperature range from 1 to 13.2°C, optimum 4.6°C (Fig. 4c).

Distribution. The highest abundances (>16 % of the total assemblages) are found off SW Svalbard and the species is relatively common (ca. 10% of the total assemblages) in Fram Strait (north of 70°N), along the East Greenland Current and in Nares Strait, western Baffin Bay and northern Labrador Sea (following the Baffin-Labrador Current). It's rare along the Norwegian margin and south of 60°N.

The response to SST in our study agrees well with previous literature, where *Bacterosira bathyomphala* (including the spore) is described as a sea ice-related species, typically found in Arctic-subarctic cold-water regions (Koç and Jansen, 1994; Hasle and Syvertsen, 1996; Andersen et al., 2004b; Krawczyk et al., 2010; 2013; Caissie, 2012). Modern observational data defines *Bacterosira bathyomphala* as a typical early spring bloomer (von Quillfeldt, 2000) and an important member of the Sea Ice/Marginal Ice Zone assemblage (Fig. 2; Andersen et al. 2004b). The response of the taxon based on the large calibration dataset used in this study shows that it can occur at similar abundances (<5%) at both low and high sea ice concentrations (Fig. 4d) showing that while this taxon is a good cold-water indicator, it cannot be used as an indicator of sea ice presence.



270 Figure 5. *Coscinodiscus marginatus*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b)
271 Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location
272 with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

274

275 *Coscinodiscus marginatus* Ehrenberg (Fig. 5)

276 References. Sancetta, 1982, p. 228, pl. 2, fig. 10; Hasle and Syvertsen, 1996, p. 107, pl. 18; Scott and Thomas,
277 2005, p. 43, fig. 2.18b.

278 Response to environmental gradients. Temperature range from 1.6 to 15.7°C, optimum 7.1°C. Statistically
279 significant relationship to SST, but not to sea ice (Fig. 5c, d).

280 Distribution. *Coscinodiscus marginatus* is not a common species in the calibration dataset and generally
281 shows low abundances (mostly <5% of the total assemblage). In the studied dataset, it was present in 51
282 surface samples (out of 183), and the highest abundances are found in SE Greenland, SW Svalbard and Baffin
283 Bay.

284 *Coscinodiscus marginatus* is described as a cosmopolitan species occurring in temperate to warm waters
285 (Hasle and Syvertsen, 1996). In the Labrador Sea, it is reported to dominate the North Atlantic assemblage
286 that has strong Atlantic water influence (De Sève, 1999). In the North Pacific it occurs north of the Subarctic
287 Front in the open North Pacific (10–14 °C), where it is rare apart from the north-eastern part (Sancetta, 1982;
288 Ren et al., 2014).

289

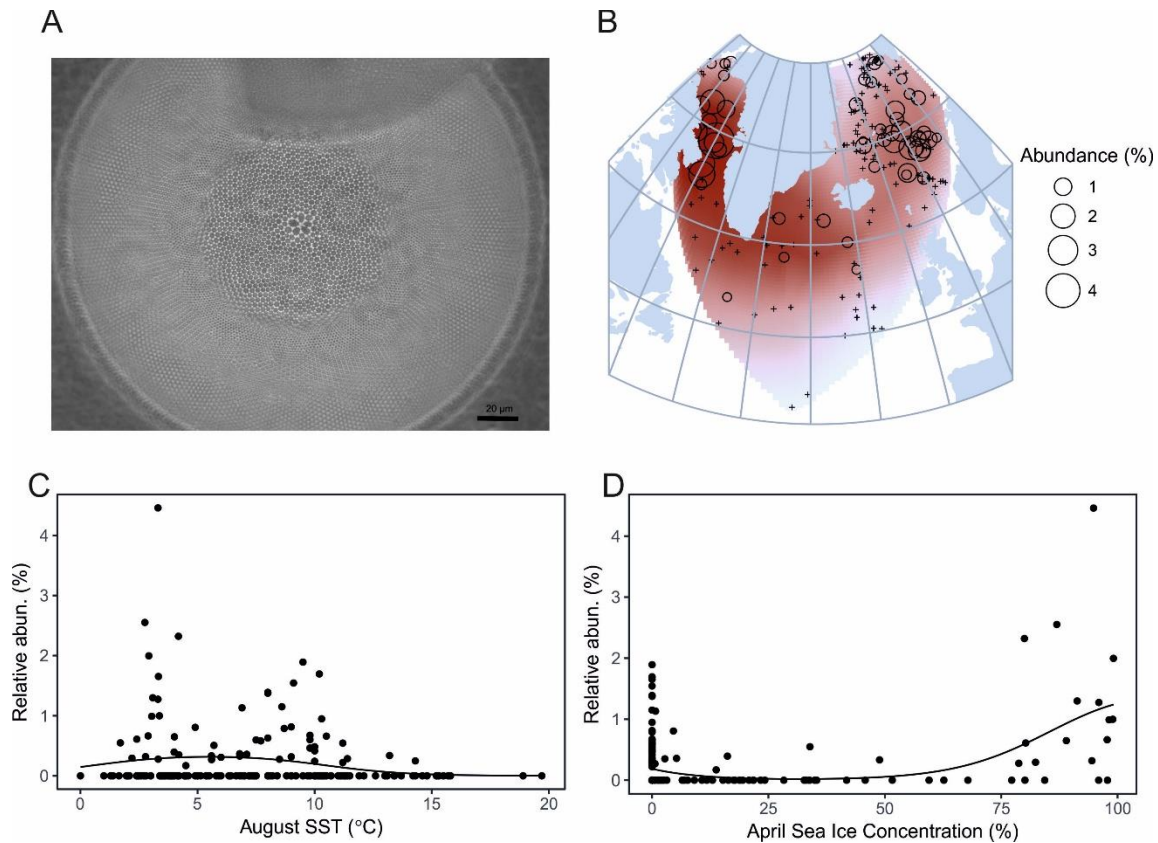


Figure 6. *Coscinodiscus oculus-iridis*. a) Light microscopy image of the species (sample from Newfoundland, core AI07-14G), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

Coscinodiscus oculus-iridis Ehrenberg (Fig. 6)

Basionym. *Coscinodiscus radiatus* var. *oculus-iridis* Ehrenberg

Synonym. *Coscinodiscus oculus-iridis* var. *genuina* Grunow, *Coscinodiscus oculus-iridis* var. *typicus* Cleve-Euler.

References. Sancetta, 1982, p. 229, pl. 2, fig. 11; Cremer, 1998, p. 21, pl. 7, fig. 1; Scott and Thomas, 2005 p. 44, fig. 2.18c.

Response to environmental gradients. Temperature range from 1.7 to 14.4°C, optimum 6.1°C. Statistically significant relationship to both SST and sea ice. Highest abundances are found at low SSTs and sea ice concentrations of 75–100% (Fig. 6d).

Distribution. Although *Coscinodiscus oculus-iridis* is a relatively common species in the studied dataset, it is found at low relative abundances (<4%). It occurs at similar abundances also in the northern Pacific (Ren et al., 2014). The taxon has its highest abundances in Baffin Bay and in the Nordic Seas (between ca. 67 and 70°N). It is also found in SE Greenland and Nares Strait.

In the North Atlantic, *Coscinodiscus oculus-iridis* is rare south of 60°N. Its response to sea ice is bimodal (with unequal peaks): while the highest abundances are reached at high sea ice concentrations, the species reaches up to 2% (relative abundances) in areas not exhibiting sea ice. Such a bi-modal distribution may point towards different varieties within the species.

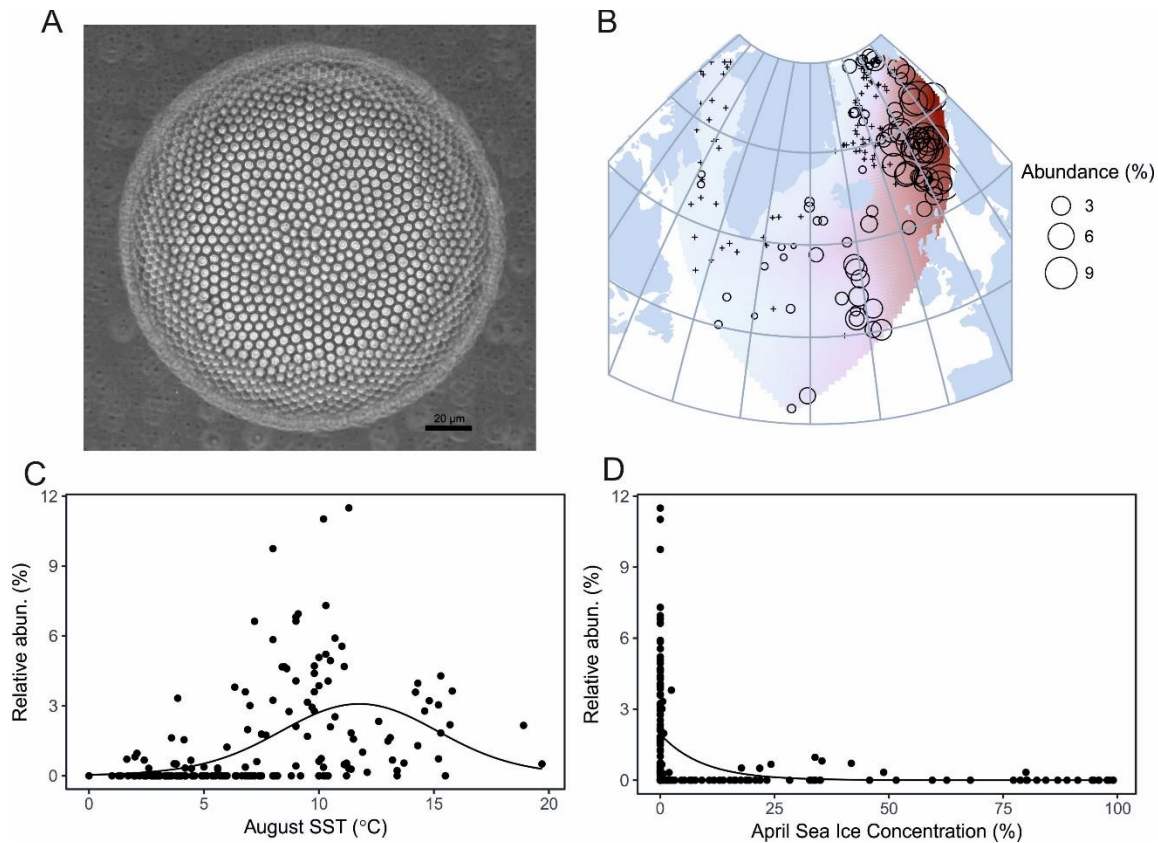


Figure 7. *Coscinodiscus radiatus*. a) Light microscopy image of the species (sample from Newfoundland, core AI07-14G), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

Coscinodiscus radiatus Ehrenberg (Fig. 7)

References. Hasle and Syvertsen, 1996, p. 107, pl. 18, figs. 6d-e; Snoeijs and Vilbaste, 1994, p. 32, pl. 120; Bérard-Therriault et al., 1999, p. 30, pl. 13d-e, 14a-c; Scott and Thomas, 2005, p. 44, fig. 2.18d; Pearce et al., 2014b, p. 444, figs. 16 and 17.

Response to environmental gradients. Temperature range from 1.6 to 19.7°C, optimum 10°C, the species has a unimodal symmetric response to SST (Fig. 7c, Table 1). *Coscinodiscus radiatus* has a statistically significant response to sea ice in our dataset with highest abundances found at 0% sea ice concentrations (Fig. 7d).

Distribution. Found in the subpolar North Atlantic and Nordic Seas, where it reaches abundances up to ca. 10 % of the total assemblage, and off western Svalbard tracing the North Atlantic current (Fig. 7b). The species is virtually absent from the Baffin Bay and Labrador Sea.

Coscinodiscus radiatus is not often discussed in the literature. According to Berner et al. (2008) it is most strongly associated with the Norwegian Atlantic Current assemblage despite not being among the most common species in the assemblage. *Coscinodiscus radiatus* can be classified as a warm- to temperate-water species (Fig. 7c), distributed along the warm North Atlantic Current. It is also common in the mixed water region off Norway and in the central North Atlantic (sensu Andersen et al., 2004a).

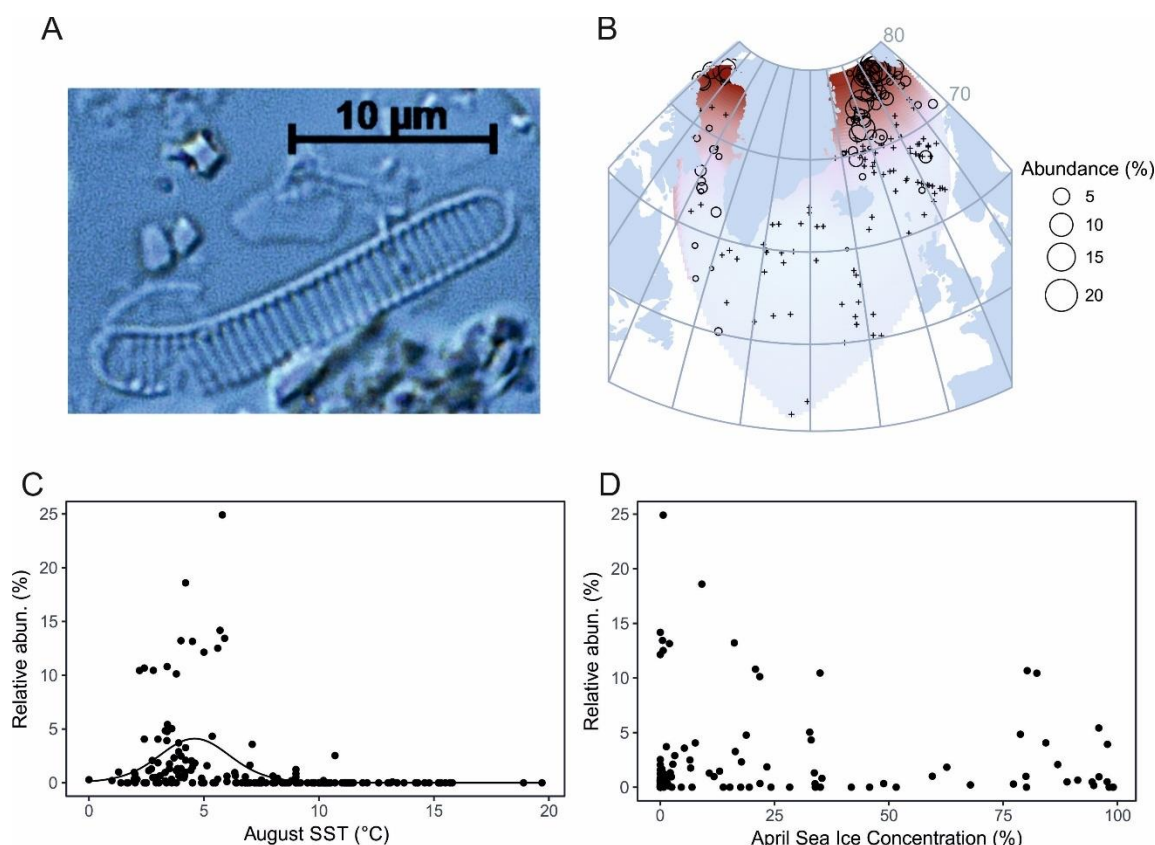


Figure 8. *Fragilariopsis cylindrus*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

Fragilariopsis cylindrus (Grunow) Krieger in Helmcke & Krieger (Fig. 8)

Basionym. *Fragilaria cylindrus* Grunow in Cleve and Moller.

Synonym. *Nitzschia cylindrus* (Grunow) Hasle. *Fragilaria nana* Steem.Niels. *Fragilariopsis cylindrus* var. *planctonica* Willi Krieg., in Helmcke & Krieger, *Fragilariopsis cylindrus* f. *minor* Manguin, *Fragilariopsis linearis* (Castrac.) Hust. var. *intermedia* Manguin, *Fragilariopsis nana* (Steen.Niels.) Paasche.

References. Snoeijis and Vilbaste, 1994, p. 50, pl. 138; Hasle and Syvertsen, 1996, p. 302, pl. 68; Cremer, 1998, p. 40, pl. 17, fig. 11; Bérard-Therriault et al., 1999, p. 64, pl. 55 g-h, 56a-b; Witkowski et al., 2000, p. 359, pl. 213, figs 8–14; Jensen, 2003, p.125, pl. 12, figs. 6–8; Scott and Thomas, 2005, p. 172, fig. 100a-e; Pearce et al., 2014b, p. 446, figs. 23 and 24.

Response to environmental gradients. Temperature range from 0 to 13.2°C, optimum 4.4°C (Fig. 8c). Statistically significant relationship to SST but not sea ice, although the species is found at relatively high abundances (5-10%) when sea ice concentrations are high (75-100%). Highest abundances at 0% sea ice concentrations (Fig. 8d).

Distribution. In the Northern Hemisphere this species is found at high abundances (up to 20% of total assemblage) in Fram Strait, off West Svalbard and south of Nares Strait in the North Water Polynya. It is mainly occurring north of 65°N, but also found in a few samples south of 60°N in the Labrador Sea.

Fragilariopsis cylindrus is described as a cold water species, found in the Arctic and the Antarctic. In the Northern Hemisphere, it has been described as very common in the Nordic Seas (Koç Karpuz and Schrader, 1990) and in Baffin Bay (Williams, 1990). It is frequently associated with sea ice and/or spring melting, and widely used as a sea ice indicator together with *Fragilariopsis oceanica* (e.g., De Sève, 1999; von Quillfeldt,

2001; Jiang et al., 2001; 2002; Jensen et al., 2004; Witak et al., 2005; Krawczyk et al., 2010; 2013; 2016; Sha et al., 2014, Miettinen et al., 2015). Although *Fragilariopsis cylindrus* shows high relative abundances at high sea ice concentrations in our dataset (Fig. 8d) and is strongly associated with the spring sea ice limit in Fram Strait (Fig. 8b), it is also common in areas either exhibiting low sea ice concentrations or ice-free conditions year round. The taxon is also a common constituent of the spring bloom in the weakly brackish northern parts of the Baltic Sea (e.g., Tuovinen et al., 2009), and is often defining diatom assemblages at the bottom of Greenlandic fjords, which receive meltwater from the ice sheet and have a lower salinity (Weckström, K. unpublished data). The species is a very good cold-water indicator with a well-defined optimum around 4–5°C (Fig. 8c). However, while *Fragilariopsis cylindrus* is clearly related to sea ice based on previous studies, its use as a sea ice indicator species is not as straightforward as previously assumed (Fig. 8d), and requires careful assessment depending on the study location (Fig. 8b).

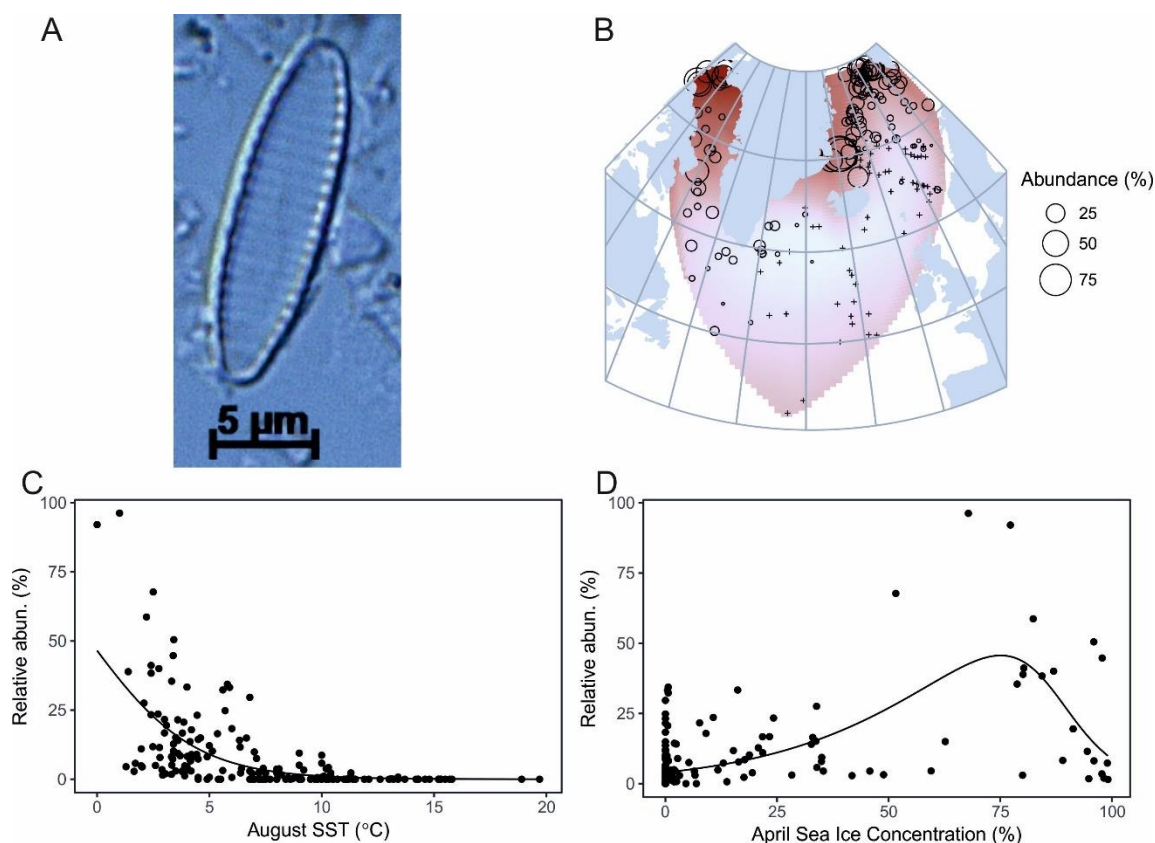


Figure 9. *Fragilariopsis oceanica*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

Fragilariopsis oceanica (Cleve) Hasle (Fig. 9)

Basionym. *Fragilaria oceanica* (Cleve).

Synonym. *Fragilaria arctica* Grunow in Cleve & Grunow, *Nitzschia grunowii* Hasle.

References. Hasle and Syvertsen, 1996, p. 299, pl. 67; Cremer, 1998, p. 40, pl. 17, figs. 9–10; Bérard-Therriault et al., 1999, p. 65, pl. 56c-f, h; Witkowski et al., 2000, p. 361, pl. 213, figs. 17–21; Jensen, 2003, p. 125, pl. 13, figs. 2–6; Pienitz et al., 2003, p. 68, pl. 22, figs. 9–14; Pearce et al., 2014b, p. 446, figs. 25–27.

386 Response to environmental gradients. Temperature range from 0 to 13.1°C, optimum 3.6°C (Fig. 9c).
 387 Statistically significant relationship to both SST and sea ice. Highest abundances are found at ca. 75% sea ice
 388 concentrations (Fig. 9d).
 389 Distribution. *Fragilariopsis oceanica* is abundant (up to 75% of total assemblages) and widely distributed in
 390 the studied dataset. Highest abundances are found along the spring Arctic sea ice limit in Fram Strait and off
 391 East Greenland and south of Nares Strait in the North Water Polynya. It should be noted that in the dataset
 392 used, the abundances of *Fragilariopsis oceanica* also likely include *Fragilariopsis reginae-jahniae* and *Fossula*
 393 *arctica*. Both are relatively new species (described in 2000 and 1996, respectively), which is the reason why
 394 they have not been included in the dataset (137 sites were analysed before these species were described).
 395 While the former generally seems to be relatively rare, the latter can occur at high abundances in the
 396 northern North Atlantic. Both species are cold-water, sea-ice related species (von Quillfeldt, 2000), which
 397 appear to have similar distributions to *Fragilariopsis oceanica*.
 398 *Fragilariopsis oceanica* is found in Arctic and subarctic cold water regions. It is widely associated with sea ice
 399 and grouped into a sea ice assemblage in several studies (e.g., Hasle and Syvertsen, 1996; Jiang et al., 2001;
 400 von Quillfeldt, 2001; Witak et al., 2005; Justwan and Koç, 2008; Krawczyk et al., 2010; 2013; Caissie, 2012).
 401 Both *Fragilariopsis oceanica* and *Fragilariopsis cylindrus* regularly occur in the marginal ice zone (MIZ) and
 402 are part of the spring bloom associated with melting ice (Jiang et al., 2001; von Quillfeldt, 2000; 2003). Their
 403 distribution in the northern North Atlantic is very similar, although *Fragilariopsis oceanica* is clearly more
 404 abundant (Fig. 9b). However, while *Fragilariopsis cylindrus* can be found in truly brackish environments (e.g.,
 405 the Baltic Sea), this is not the case for *Fragilariopsis oceanica*, which is completely absent from the Baltic Sea
 406 and often rarer than *Fragilariopsis cylindrus* at the bottom of Greenlandic fjords (Weckström, K., unpublished
 407 data). The species has an even lower optimum to SST than *Fragilariopsis cylindrus*, displaying highest
 408 abundances below 3°C. While the potential inclusion of *Fragilariopsis reginae-jahniae* in the total abundances
 409 of *Fragilariopsis oceanica* is not likely affecting the obtained results (due to its apparent rarity), the inclusion
 410 of *Fossula arctica* could have an effect on these. Although *Fossula arctica* and *Fragilariopsis oceanica* appear
 411 to have similar ecological requirements, more work is clearly needed to define their ecology and distribution.
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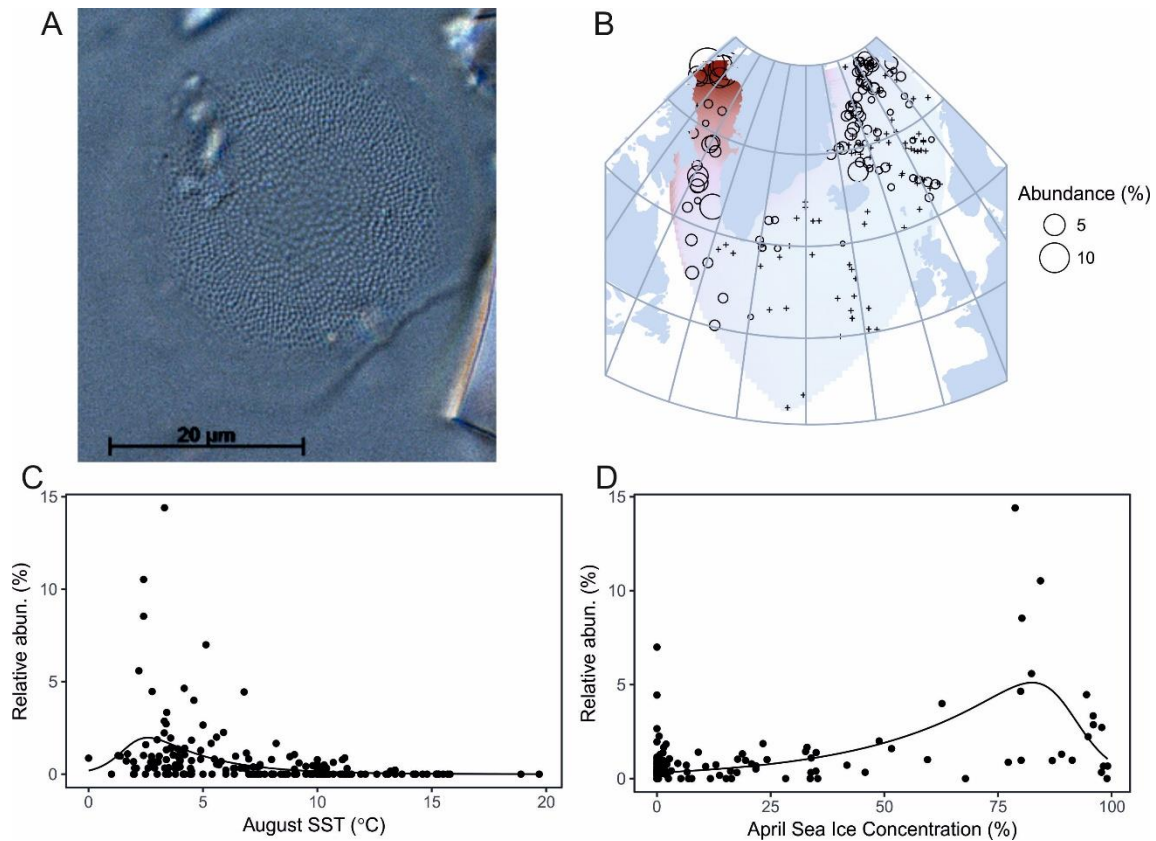


Figure 10. *Porosira glacialis*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

Porosira glacialis (Grunow) Jørgensen (Fig. 10)

Basionym. *Podosira hormoides* var. *glacialis* Grunow.

Synonyms. *Podosira glacialis* (Grunow) Cleve, *Lauderia glacialis* (Grunow) Gran, *Porosira antarctica* O.G. Kozlova.

References. Sancetta, 1982, p. 235, pl. 3, figs. 16–18; Hasle and Syvertsen, 1996, p. 41, pl 3; Cremer, 1998, p. 71, pl. 34, fig. 7; Snoeijs and Balashova, 1998, p. 87, pl. 475; Bérard-Therriault et al., 1999, p. 21, pl. 3d, f-h; Jensen, 2003, p. 119, pl. 6, figs. 8–10; Scott and Thomas, 2005, p. 84, fig. 2.41a-f; Pearce et al., 2014b, p. 448, figs. 36–37.

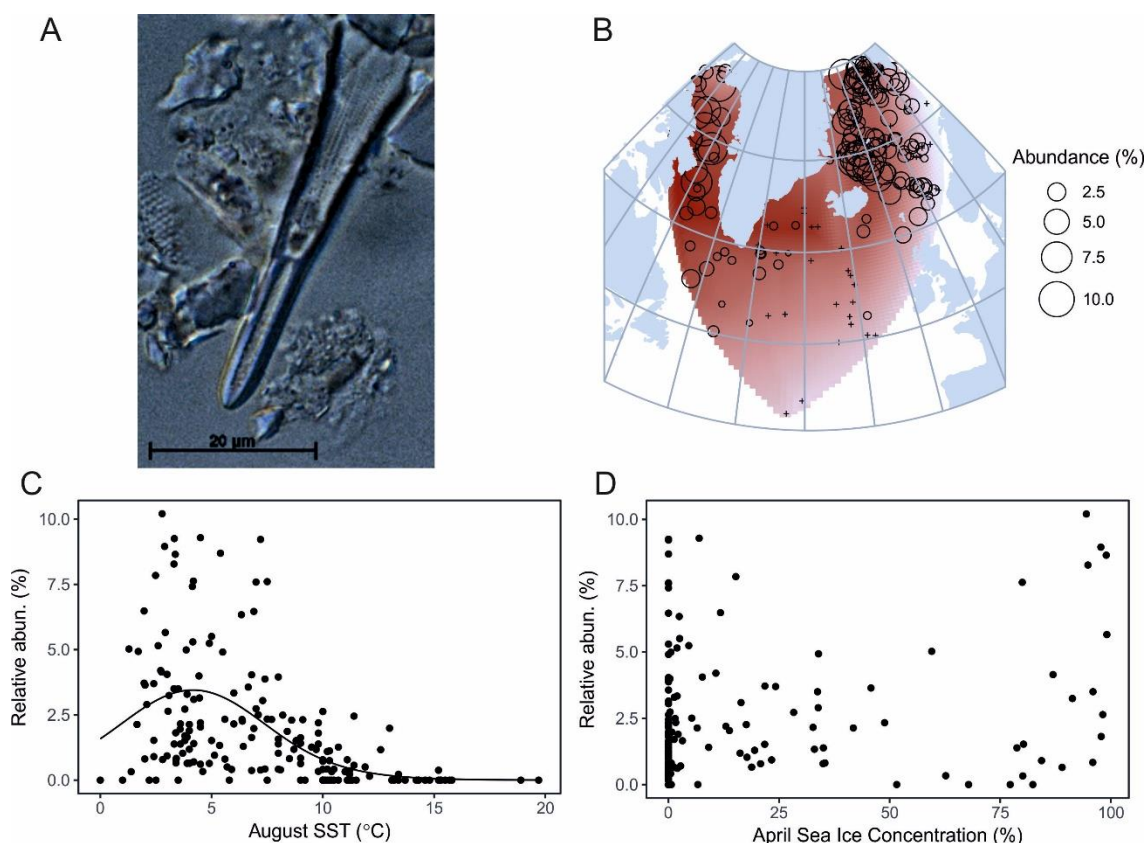
Response to environmental gradients. Temperature range from 0 to 13.4°C, optimum 4.3°C (Fig. 10c). Statistically significant relationship to both SST and sea ice. Highest abundances at 75–100% sea ice concentrations (Fig. 10d).

Distribution. In the studied dataset, highest abundances of *Porosira glacialis* are found south of Nares Strait in the North Water Polynya, Davis Strait, Baffin Bay and north of Iceland (Fig. 10b). It is also relatively abundant east of Greenland along the spring Arctic sea ice limit. Compared to e.g., *Fragilariopsis oceanica*, *Porosira glacialis* is much rarer, not exceeding 10% of the total assemblages at our sites.

Porosira glacialis has been described as an Arctic species, but it is found from cold to temperate waters, and also in the Southern Ocean (Hasle and Syvertsen, 1996; Pike et al., 2009; Krawczyk et al., 2013). *Porosira glacialis* is often associated with sea ice and grouped into a sea ice assemblage in several studies in (Koç Karpuz and Schrader, 1990; Justwan and Koç, 2008; Krawczyk et al., 2016). The species thrives in the Marginal Ice Zone occurring during and after the spring bloom, yet not as a dominating species (von Quillfeldt, 2000), which is also evident in our dataset where highest abundances are <10% of the total assemblages. *Porosira*

441 glacialis can be used as an indicator species for low SST and high sea ice concentrations (highest abundances
 442 around 75% sea ice concentrations).

443
 444
 445



446
 447 Figure 11. *Rhizosolenia hebetata* f. *hebetata*. a) Light microscopy image of the forma (sample from Baffin Bay, core SL-
 448 170), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to
 449 location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

450

451 *Rhizosolenia hebetata* Bailey f. *hebetata* (Fig. 11)

452 Synonym. *Rhizosolenia hebetata* f. *hiemalis* Gran.

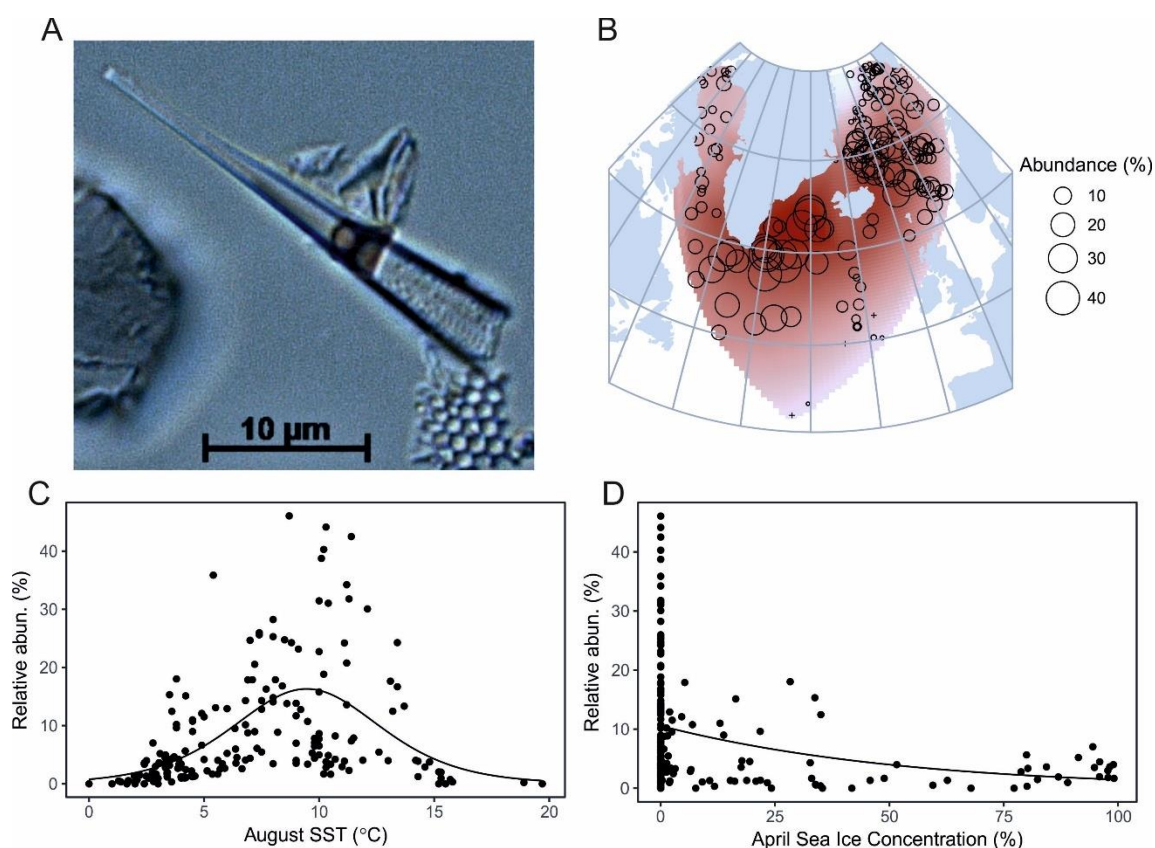
453 References. Sancetta, 1982, p. 237, pl. 4, figs. 5–6; Hasle and Syvertsen, 1996, p. 149, pl. 27; Bérard-Therriault
 454 et al., 1999, p. 36, pl. 21a-c.

455 Response to environmental gradients. Temperature range from 1.3 to 15.2°C, optimum 5.1°C (Fig. 11c).
 456 Statistically significant relationship to SST, but not to sea ice. Reaches highest abundances (ca. 10%) both in
 457 ice-free conditions and in near full sea ice cover (Fig. 11d).

458 Distribution. *Rhizosolenia hebetata* f. *hebetata* is very common in the studied dataset and present in most
 459 of the samples, excluding the south-east sector of the North Atlantic region. Generally, *Rhizosolenia hebetata*
 460 f. *hebetata* occurs at relatively low abundances (<10%), the highest abundances are found at high latitudes
 461 (above ca. 65°N) in Baffin Bay, south of Nares Strait, the Nordic Seas and Fram Strait.

462 *Rhizosolenia hebetata* f. *hebetata* is described as a northern cold water region species and defined as an
 463 important contributor to the Arctic water assemblage (Fig. 2, Andersen et al., 2004b) and to the Northern
 464 Cold Water assemblage (Krawczyk et al., 2010; 2013). It is a clear cold water indicator with an SST optimum
 465 around 5°C (Fig. 11c). Although it has a relatively similar distribution to many sea-ice-related species,
 466 *Rhizosolenia hebetata* f. *hebetata* shows no relationship to sea ice, suggesting this forma appears later in the

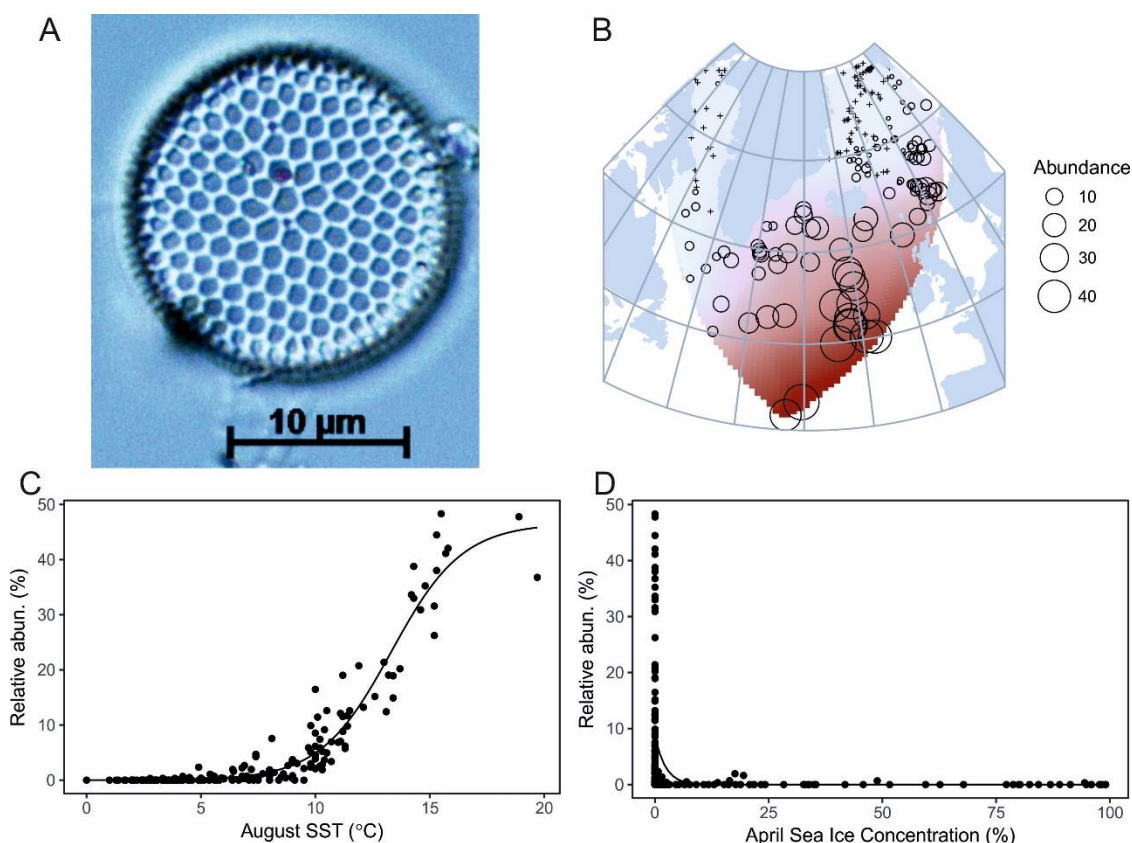
467 season in regions where sea ice is present, occurring after the cold and fresher spring meltwater layer has
 468 broken up.



471
 472 Figure 12. *Rhizosolenia hebetata* f. *semispina*. a) Light microscopy image of the form (sample from Baffin Bay, core SL-
 473 170), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to
 474 location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

475
 476 *Rhizosolenia hebetata* f. *semispina* (Hensen) Gran (Fig. 12)
 477 Basionym. *Rhizosolenia semispina* Hensen.
 478 Synonym. *Rhizosolenia styliformis* var. *semispina* (Hensen) G.Karst
 479 References. Snoeijs and Kasperovičienė, 1996, p. 101, pl. 389; Hasle and Syvertsen, 1996, p. 149, pl. 27;
 480 Bérard-Therriault et al., 1999, p. 36, pl. 21d, e, i, k; Jensen, 2003, p. 120, pl. 6, figs 5–7; Scott and Thomas,
 481 2005, p. 81, fig. 2.37c; Pearce et al., 2014b, p. 448, figs. 39–40.
 482 Response to environmental gradients. Temperature range from 1.3°C to 18.9°C, optimum temperature 8.5°C
 483 (Fig. 12c). Statistically significant relationship to both SST and sea ice. Highest abundances (>40%) are found
 484 in ice-free regions (Fig. 12d).
 485 Distribution. *Rhizosolenia hebetata* f. *semispina* is very abundant in the northern North Atlantic and was
 486 found in almost every sample in the dataset. Highest abundances (up to 40%) are found in SE Greenland/NE
 487 Labrador Sea, around Iceland and from the Nordic Seas.
 488 Previously *Rhizosolenia hebetata* f. *semispina* has been show to occur in northern cold water regions (Hasle
 489 and Syvertsen, 1996). It is further described as an important contributor to the Arctic Water and Subarctic
 490 Water assemblages (Fig. 2; Andersen et al., 2004b) and to the Arctic-Norwegian Waters Mixing assemblage
 491 (Koç Karpuz and Schrader, 1990). The distribution of *Rhizosolenia hebetata* f. *semispina* in the studied dataset
 492 corresponds to the distributions of these assemblages. Compared to the distribution of *Rhizosolenia*

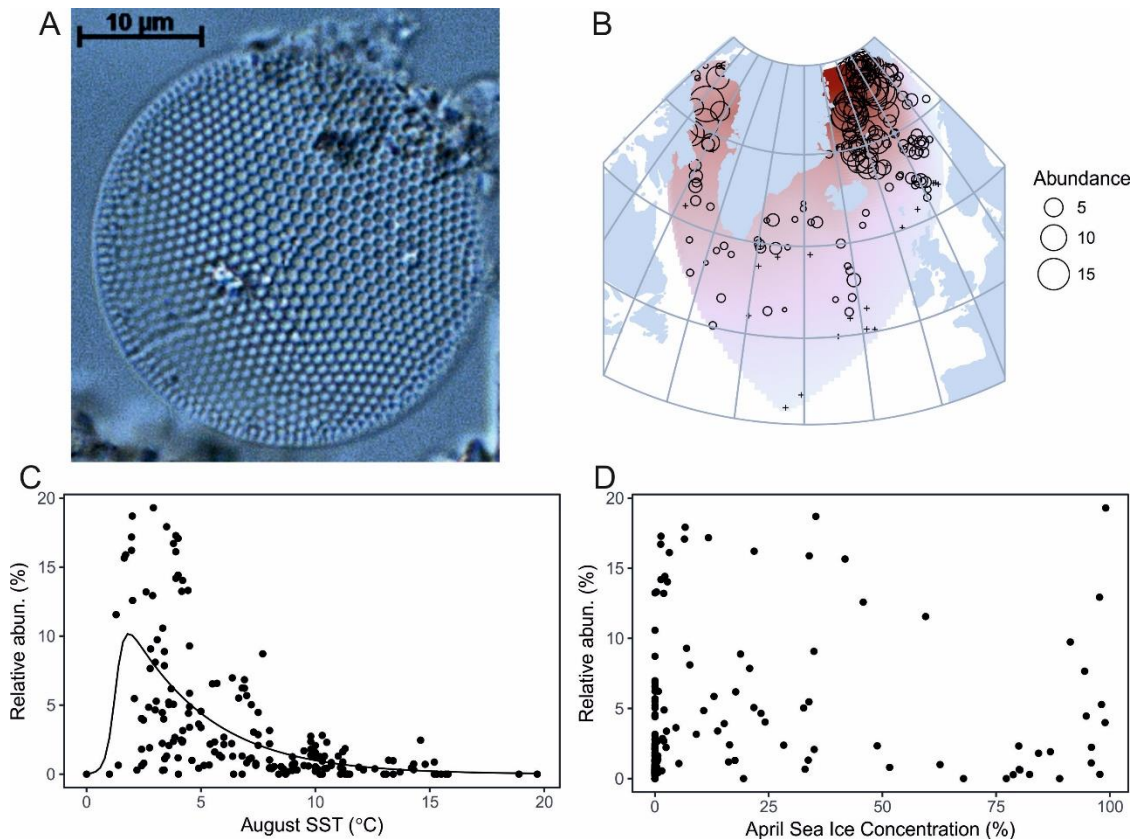
493 hebetata f. hebetata in our dataset, highest abundances of *Rhizosolenia hebetata* f. *semispina* are found in
 494 warmer waters, around ca. 10°C (Fig. 12c) and it is abundant also below ca. 65°N, whereas *Rhizosolenia*
 495 hebetata f. hebetata is most abundant above this latitude (Fig. 12b). The distribution of *Rhizosolenia hebetata*
 496 f. *semispina* roughly follows the Polar Front.
 497
 498



499
 500 Figure 13. *Shionodiscus oestrupii*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b)
 501 Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location
 502 with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.
 503

504 *Shionodiscus oestrupii* (Ostenfeld) Alverson, Kang et Theriot (Fig. 13)
 505 Basionym. *Coscinosira oestrupii* Ostenfeld.
 506 Synonym. *Thalassiosira oestrupii* (Ostenfeld) Hasle: *Thalassiosira antiqua* var. *septata* Proshkina-Lavrenko.
 507 References. Snoeijs and Kasperovičienė, 1996, p. 109; Hasle and Syvertsen, 1996, p. 83, pl. 12; Jensen, 2003,
 508 p. 123, pl. 11, figs. 1–2; Scott and Thomas, 2005, p. 108, fig. 2.56; Pearce et al., 2014b, p. 453, figs. 66–67.
 509 Response to environmental gradients. Temperature range from 2.8 to 19.7°C, optimum 13.4°C. Statistically
 510 significant relationship to SST and sea ice, virtually absent in areas with seasonal sea ice cover (Fig. 13c, d).
 511 Distribution. Very abundant in the North Atlantic. Highest abundances in our dataset (up to 40%) are found
 512 at latitudes between 40–60°N and along the warm and saline North Atlantic and Irminger Currents (Fig. 13b).
 513 *Shionodiscus oestrupii* is described as a cosmopolitan species that prefers warm to temperate (Atlantic)
 514 waters and higher salinities (Hasle and Syvertsen, 1996; Koç Karpuz and Schrader, 1990; Jiang et al., 2001;
 515 Andersen et al., 2004b). The distribution of *Shionodiscus oestrupii* reflects the North Atlantic Current
 516 assemblage in Andersen et al. (2004b) (Fig. 2), as it is the main species in the assemblage. In Baffin Bay,
 517 *Shionodiscus oestrupii* has been described as part of the Warm/temperate water assemblage propagating
 518 north along the West Greenland margin (Krawczyk et al., 2010; 2013). In our data set, *Shionodiscus oestrupii*

519 does not appear north of Davis Strait, however, our dataset does not include sites close to the SW and W
 520 Greenland margins (Fig. 13b). *Shionodiscus oestrupii* can be defined as a very robust warm (Atlantic) water
 521 indicator.



525
 526 Figure 14. *Shionodiscus trifultus*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b)
 527 Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location
 528 with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

529
 530 *Shionodiscus trifultus* (G. Fryxell) Alverson, Kang et Theriot (Fig. 14)
 531 Basionym. *Thalassiosira trifulta* G. Fryxell in Fryxell & Hasle.
 532 References. Sancetta, 1982 p. 244, pl. 5, figs. 10–12, pl. 6, figs. 1–2; Hasle and Syvertsen, 1996, p. 87, pl. 12;
 533 Scott and Thomas, 2005, p. 114, fig. 2.63a-f.
 534 Response to environmental gradients. Temperature range from 1.3 to 15.2°C, optimum 4.4°C. Statistically
 535 significant relationship to SST but not to sea ice occurring at equally high abundances in both high and low
 536 sea ice concentrations (Fig. 14c, d).
 537 Distribution. Most abundant in our data set (up to 15%) at high latitudes in Fram Strait, Nordic Seas and
 538 northern Baffin Bay.
 539 *Shionodiscus trifultus* is described as an indicator for cold water (Caissie, 2012) and it is an important
 540 contributor to the Greenland Arctic Waters assemblage in Andersen et al. (2004b) (Fig. 2) alongside
 541 *Thalassiosira anguste-lineata*. In Baffin Bay, *Shionodiscus trifultus* has also been described as a minor
 542 contributor to the summer pack ice assemblage (Williams, 1986). Based on existing literature and our results,
 543 *Shionodiscus trifultus* is a robust cold-water indicator species (Fig. 14b, c, d).

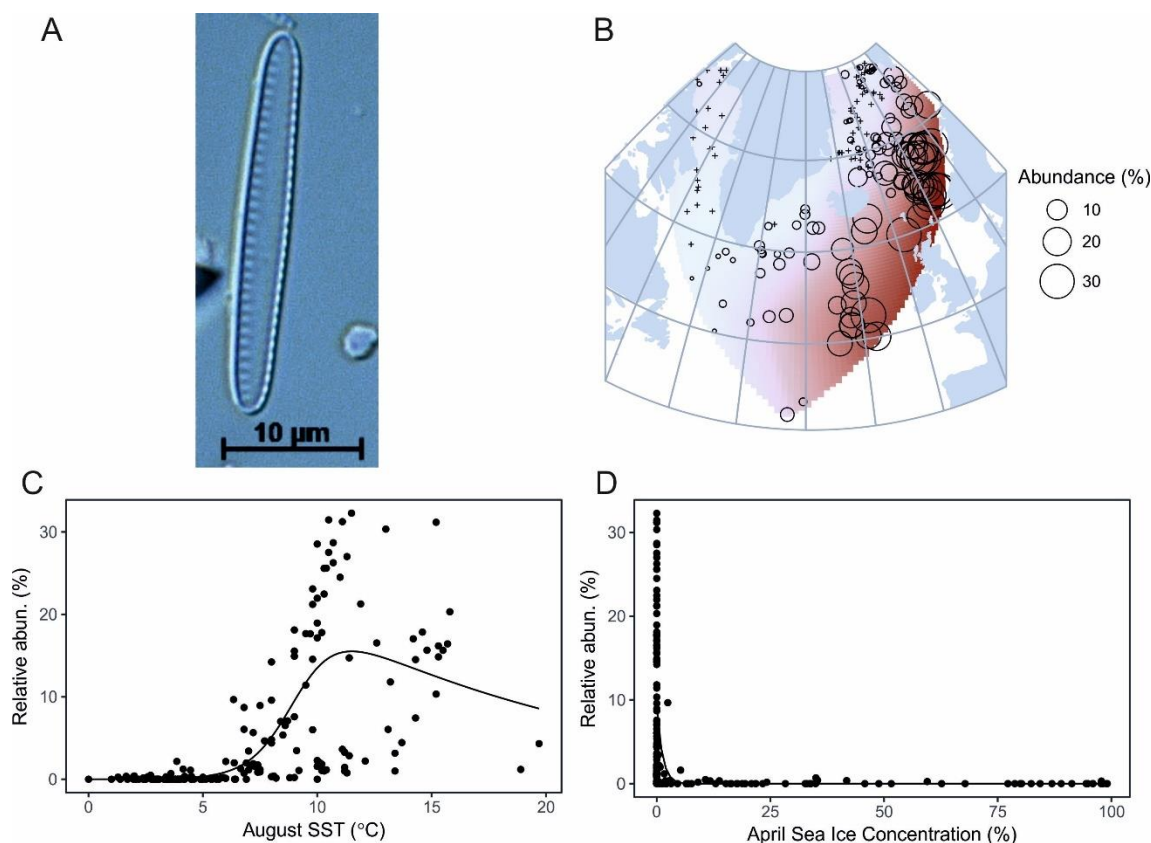


Figure 15. *Thalassionema nitzschioides*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

Thalassionema nitzschioides (Grunow) ex Mereschkowsky (Fig. 15)

Basionym. *Synedra nitzschioides* Grunow.

Synonyms. *Synedra nitzschioides* Grunow, *Thalassiothrix nitzschioides* (Grunow) Grunow in Van Heurck, *Synedra nitzschioides* var. *minor* Cleve, *Thalassiothrix curvata* Castracane, *Thalassiothrix frauenfeldii* var. *nitzschioides* (Grunow) Jörgensen.

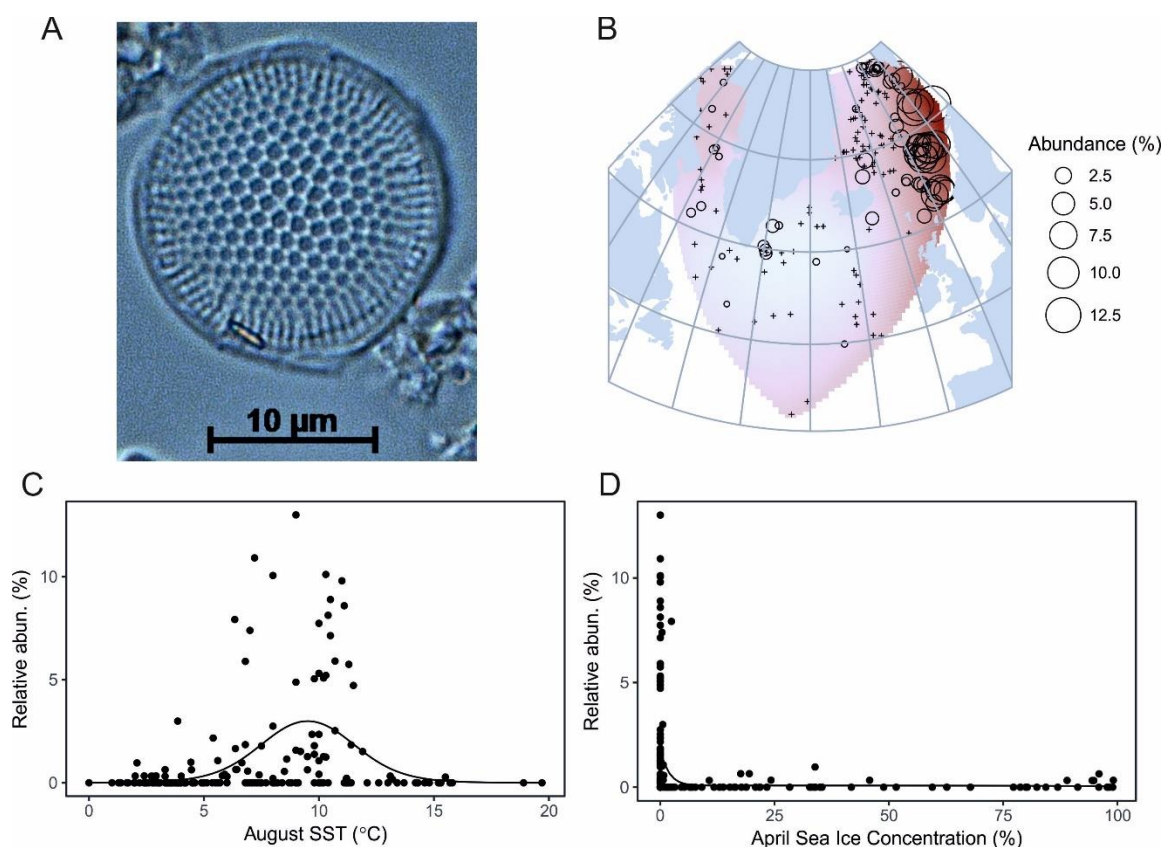
References. Sancetta, 1982, p. 239, pl. 4, figs. 11–13; Snoeijls and Vilbaste, 1994, p. 106, pl. 194; Metzeltin and Witkowski, 1996, p. 118, 128; Hasle and Syvertsen, 1996, p. 257, pl. 55–57; Bérard-Therriault et al., 1999, p. 58, pl. 48d, e, g; Pienitz et al., 2003, p. 31, pl. 8, figs. 5–10; Scott and Thomas, 2005, p. 144, fig. 2.80; Pearce et al., 2014b, p. 452, figs. 46–49.

Response to environmental gradients. Temperature range from 1.3 to 19.7°C, optimum 11.1°C. Statistically significant relationship to SST and sea ice (Fig. 15c, d).

Distribution. Although *Thalassionema nitzschioides* is an abundant species in the northern North Atlantic, its distribution closely follows the warm waters of the North Atlantic Current. Highest abundances (up to 30%) are found along the North Atlantic Current from around 50°N up to the southern tip of the Svalbard archipelago in ice-free areas (15b).

Thalassionema nitzschioides is described as a warm/temperate cosmopolitan species, excluding the high Arctic and Antarctic regions (Sancetta, 1982; Hasle and Syvertsen, 1996; Jiang et al., 2001; Krawczyk et al., 2010; 2014). In the northern North Atlantic, it is tightly associated with Atlantic Water and described as the main contributor to the Norwegian-Atlantic Current assemblage and also contributes to the North Atlantic Current assemblage (Fig. 2; Koç Karpuz and Schrader, 1990; Andersen et al., 2004b). Jiang et al. (2001) found

571 high abundances of *Thalassionema nitzschioides* in the Mixing Diatom assemblage (assemblage influenced
 572 by both the warm Irminger Current and the cold East Greenland and East Iceland Currents) and in the warm
 573 water diatom assemblage. In the studied dataset, *Thalassionema nitzschioides* was present only in one
 574 sample from the Baffin Bay region. It has, however, been found along the continental shelves and has in
 575 earlier literature been defined as a coastal planktonic species (Williams, 1986 and references therein).
 576 *Thalassionema nitzschioides* is rare in areas influenced only by cold currents showing highest abundances at
 577 SSTs between ca. 10 and 15°C (Fig. 15c). This species can be considered a reliable warm (Atlantic) water
 578 indicator.
 579



580
 581 Figure 16. *Thalassiosira angulata*. a) Light microscopy image of the species (sample from Southeast Greenland, core
 582 MD99-2322), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol +
 583 refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

584
 585 *Thalassiosira angulata* (Gregory) Hasle (Fig. 16)

586 Basionym. *Orthosira angulata* Gregory.

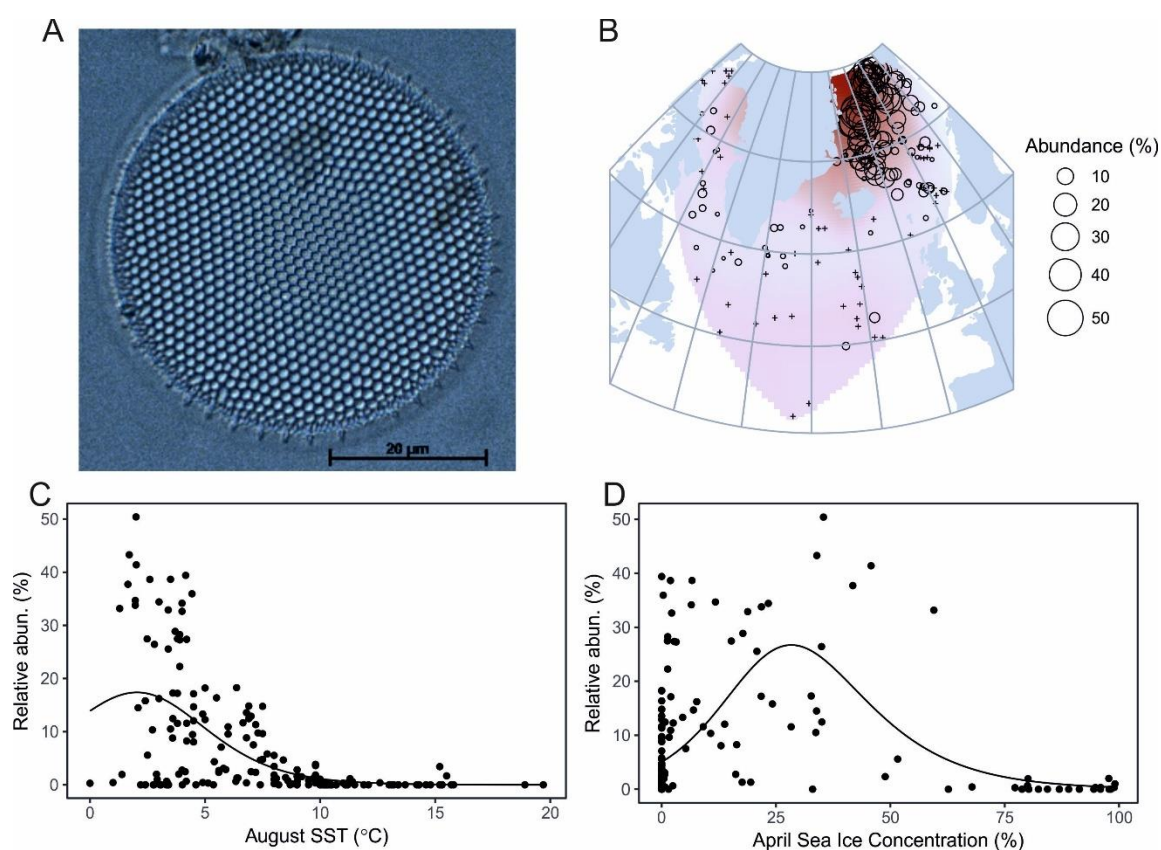
587 Synonyms. *Thalassiosira decipiens* (Grunow) Jørgensen non *Thalassiosira decipiens* (Grunow) Jørgensen in
 588 Hasle 1979.

589 References. Hasle and Syvertsen, 1996, p. 51, pl. 4; Cremer, 1998, p. 76, pl. 37, figs. 2–3; Jensen, 2003, p.
 590 120, pl. 7, fig. 1; Pearce et al., 2014b, p. 452, figs. 50–51.

591 Response to environmental gradients. Temperature range from 2.0 to 15.5°C, optimum 9.1°C. Statistically
 592 significant relationship to SST and sea ice. (Fig. 16c, d).

593 Distribution. Highest abundances (up to 12.5 %) are observed in the Nordic Seas under the North Atlantic
 594 Current. Present also at low abundances in Baffin Bay, Labrador Sea and SE-Greenland. Very rare south of
 595 60°N.

596 *Thalassiosira angulata* has been described as a subarctic and temperate species (Hasle and Syvertsen, 1996)
 597 with the main distribution area in the North Atlantic (von Quillfeldt, 2000). It is an important contributor to
 598 the Norwegian-Atlantic Current assemblage between Norway and Iceland (Fig. 2; Andersen et al., 2004b),
 599 also contributing to the Warm/Temperate Water assemblage in Baffin Bay described by Krawczyk et al., (2010;
 600 2013). In our dataset *Thalassiosira angulata* has a very similar distribution to *Thalassionema nitzschioides*,
 601 but prefers slightly colder waters, between ca. 5 and 10°C and, unlike *Thalassionema nitzschioides*, is rare
 602 below 60°N (Fig. 16b). This, together with a well-defined temperature optimum would suggest it is a robust
 603 indicator species for temperate-water and ice-free conditions.



607
 608 Figure 17. *Thalassiosira anguste-lineata*. a) Light microscopy image of the species (sample from Southeast Greenland,
 609 core MD99-2322), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol
 610 + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations. Note:
 611 The subcentral arcs of strutted processes are not clearly visible in more heavily silicified specimens such as illustrated
 612 here.

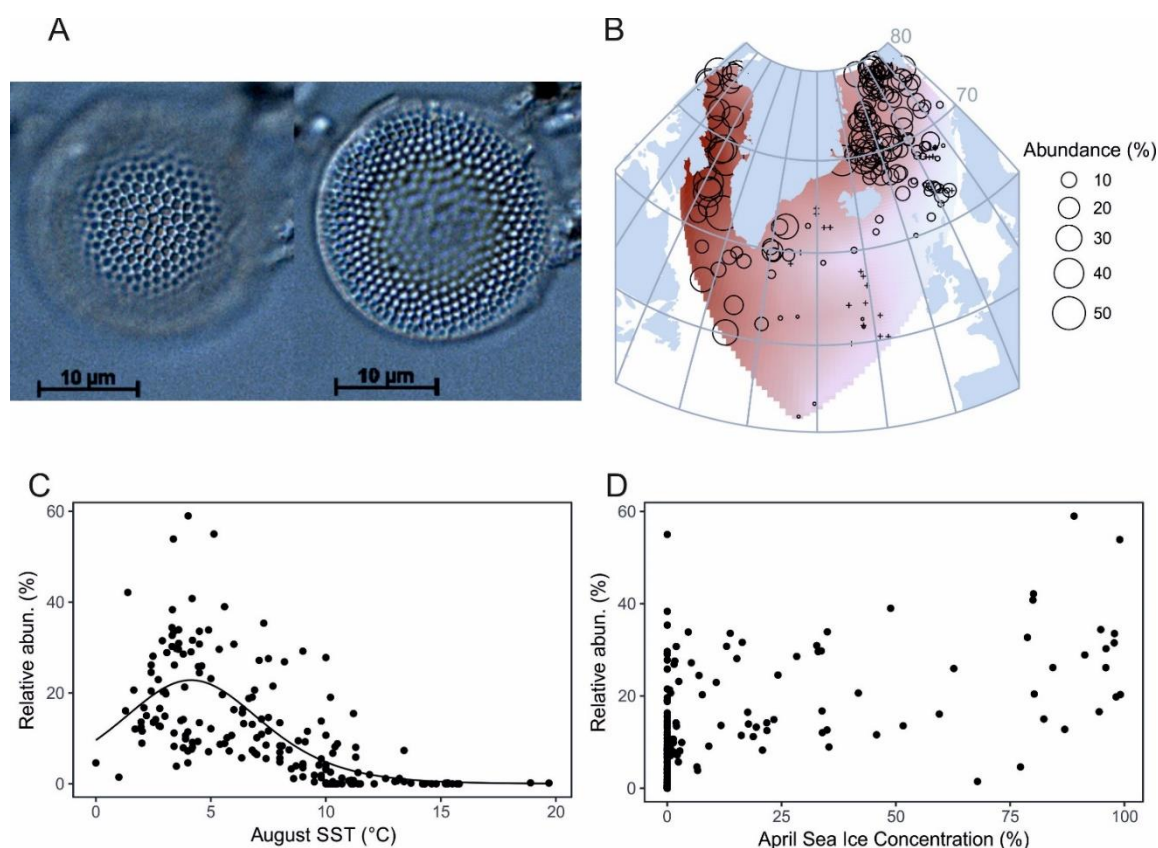
614 *Thalassiosira anguste-lineata* (A. Schmidt) G. Fryxell & Hasle (Fig. 17)

615 Basionym. *Coscinodiscus anguste-lineatus* A. Schmidt.

616 Synonyms. *Coscinodiscus polychordus* Gran, *Thalassiosira polychorda* (Gran) Jørgensen, *Coscinosira*
 617 *polychorda* (Gran) Gran., *Coscinodiscus anguste-lineatus* A. Schmidt, *Thalassiosira ornata* Proschkina-
 618 Lavrenko.

619 References. Hasle and Syvertsen, 1996, p. 71, pl. 9; Cremer, 1998, p. 77, pl. 37, fig. 6; Snoeijs and Balashova,
 620 1998, p. 106, pl. 494; Bérard-Therriault et al., 1999, p. 22, pl. 4b-d; Jensen, 2003, p. 120, pl. 7, figs. 2-4; Pearce
 621 et al., 2014b, p. 452, figs. 53–54.

622 Response to environmental gradients. Temperature range from 0 to 15.5°C, optimum 4.0°C (Fig. 17c).
 623 Statistically significant relationship with SST and sea ice. Highest abundances appear between 25 and 50%
 624 sea ice concentrations (Fig. 17d).
 625 Distribution. The highest abundances (up to 50%) of *Thalassiosira anguste-lineata* are tightly centered in the
 626 northeastern North Atlantic (the Nordic Seas and Fram Strait). It also appears at clearly lower abundances
 627 (<10%) in Baffin Bay and Davis Strait and is very rare south of 60°N (Fig. 17b).
 628 *Thalassiosira anguste-lineata* is described as a cosmopolitan species by Hasle and Syvertsen, (1996). It is
 629 found in the late Arctic spring bloom, although not as a dominant species (von Quillfeldt, 2000). *Thalassiosira*
 630 *anguste-lineata* is one of the two main contributors to the Greenland Arctic Waters assemblage (Fig. 2), most
 631 commonly occurring in the Greenland Sea (Andersen et al., 2004b). It also contributes to the Northern Cold
 632 Water diatoms assemblage in Baffin Bay (Krawczyk et al., 2013). In our dataset, *Thalassiosira anguste-lineata*
 633 is clearly associated with low temperatures (highest abundances at SSTs <5°C), and with Arctic water inflow
 634 to the North Atlantic (Fig. 17b, c).



638
 639
 640 Figure 18. *Thalassiosira antarctica* var. *borealis* resting spore. a) Light microscopy images of the variety (sample from
 641 Baffin Bay, core SL-170), b) Geographical distribution (dark red shading indicates where abundances are highest, and
 642 symbol + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

643
 644 *Thalassiosira antarctica* Comber var. *borealis* resting spore (Fig. 18)
 645 Synonyms. *Thalassiosira antarctica* var. *borealis* G. Fryxell, Doucette & Hubbard; *Thalassiosira fallax* Meunier.
 646 References. Sancetta, 1982, p. 240, pl. 4, figs. 14–15; Hasle and Syvertsen, 1996, p. 66, pl. 8; Jensen, 2003, p.
 647 120, pl. 7, figs. 5–9; Cremer, 1998, p. 77, pl. 38, figs 1–4.

648 Response to environmental gradients. Temperature range from 0 to 19.7°C, optimum 4.9°C. Statistically
 649 significant relationship to SST but not to sea ice (Fig. 18c, d).
 650 Distribution. Very abundant in our dataset, excluding the SE North Atlantic region. Highest abundances are
 651 found in Baffin Bay, Labrador Sea, Nordic Seas, Fram Strait and off East Greenland.
 652 Previously published literature often discusses *Thalassiosira gravida* spore, yet *Thalassiosira gravida* does
 653 not form resting spores (Hasle and Syvertsen, 1996) and the species described as *Thalassiosira gravida* spore
 654 is likely *Thalassiosira antarctica* var. *borealis* resting spore. *Thalassiosira antarctica* var. *borealis* resting spore
 655 may also have in older studies been called *Coscinodiscus subglobosus* Cleve et Grunow in Grunow (Hasle and
 656 Syvertsen, 1996). Recently, spores with great resemblance to *Thalassiosira antarctica* var. *borealis* resting
 657 spore have been described as *Thalassiosira kushirensis* spore (e.g., Krawczyk et al., 2010; 2012; 2016), which
 658 has been associated with warmer (Atlantic-sourced) waters (Krawczyk et al., 2013). More recently, this
 659 ecological interpretation has been challenged and the *Thalassiosira kushirensis* spore was shown to be a cold-
 660 water indicator (Weckström et al., 2014), however, associated with slightly warmer summer surface water
 661 temperatures (Krawczyk et al., 2014).
 662 *Thalassiosira antarctica* var. *borealis* resting spore (including spores previously named *Thalassiosira gravida*)
 663 has in previous literature been described as a cold-water taxon associated with Arctic waters and sea ice
 664 (Sancetta, 1981; Williams, 1984; 1986; Koç Karpuz and Schrader, 1990; De Sève, 1999; Jiang et al., 2001;
 665 Andersen et al., 2004b; Justwan and Koç, 2008). The Arctic Water assemblage in Andersen et al. (2004b) (Fig.
 666 2) mainly consist of *Thalassiosira antarctica* var. *borealis* resting spore and it is also included as an important
 667 taxon in the Sea Ice/Marginal Ice Zone assemblage. It is common in the Arctic Ocean spring bloom, however,
 668 occurring later than the *Fragilariopsis* species and *Fossula arctica* (von Quillfeldt, 2000; 2003). Although *T.*
 669 *antarctica* var. *borealis* resting spore has previously been associated with sea ice, in our data set there is no
 670 clear relationship (Fig. 18d) and the taxon is abundant also in areas, which are ice-free year round (Fig. 18b).
 671 This spore is one of the most common North Atlantic taxa today and one of the most dominant constituent
 672 of fossil diatom assemblages during the Holocene (see references above) and beyond (e.g., Oksman et al.,
 673 2017b). Due to its importance for paleoclimate reconstructions, more detailed taxonomic work (including
 674 diatom cultures) are needed to resolve if the spores identified as either *Thalassiosira gravida* r.s. or
 675 *Thalassiosira antarctica* var. *borealis* r.s., and the spores described in Krawczyk et al. (2012) as *Thalassiosira*
 676 *kushirensis* r.s. are actually the same taxon, and further, if morphologically distinct spore types depending on
 677 water temperature can be defined. Finally, it has not been resolved which vegetative cell morphotype
 678 produces the (or these) spore(s).
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 680

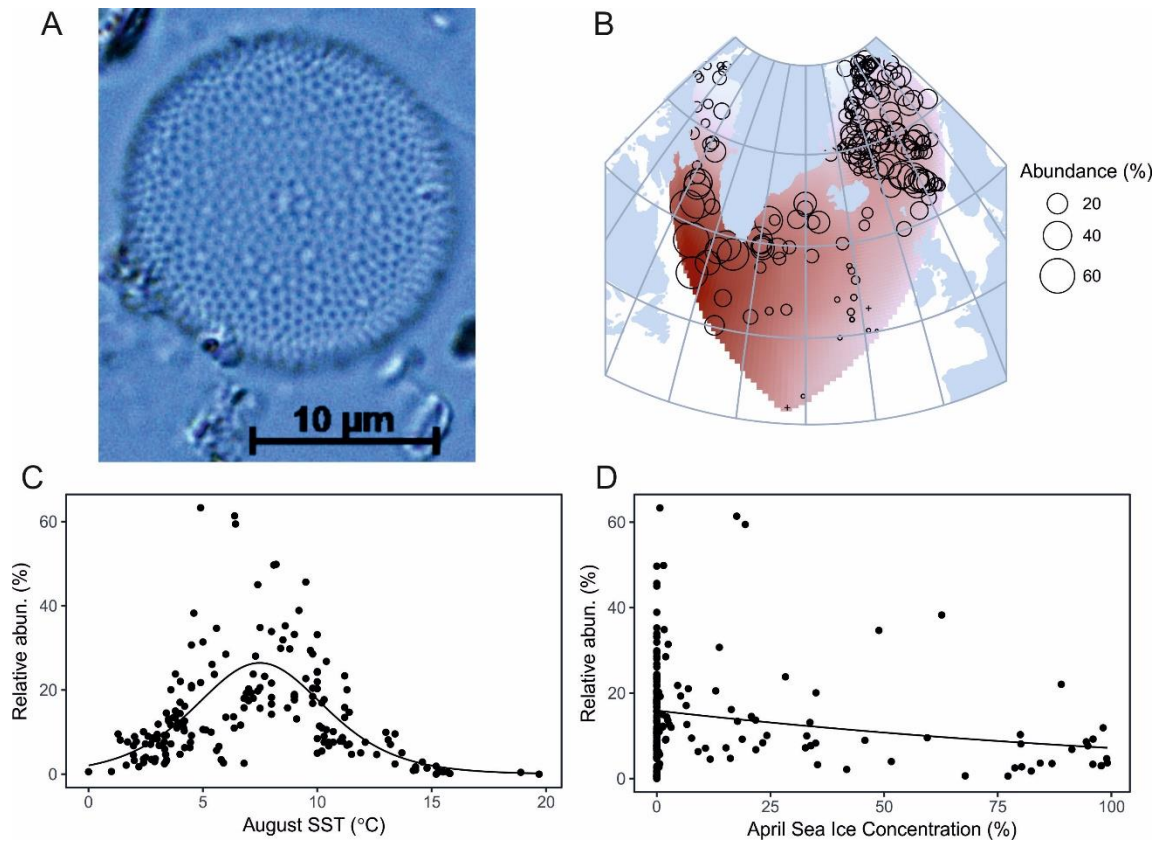


Figure 19. *Thalassiosira gravida*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

Thalassiosira gravida Cleve (Fig. 19)

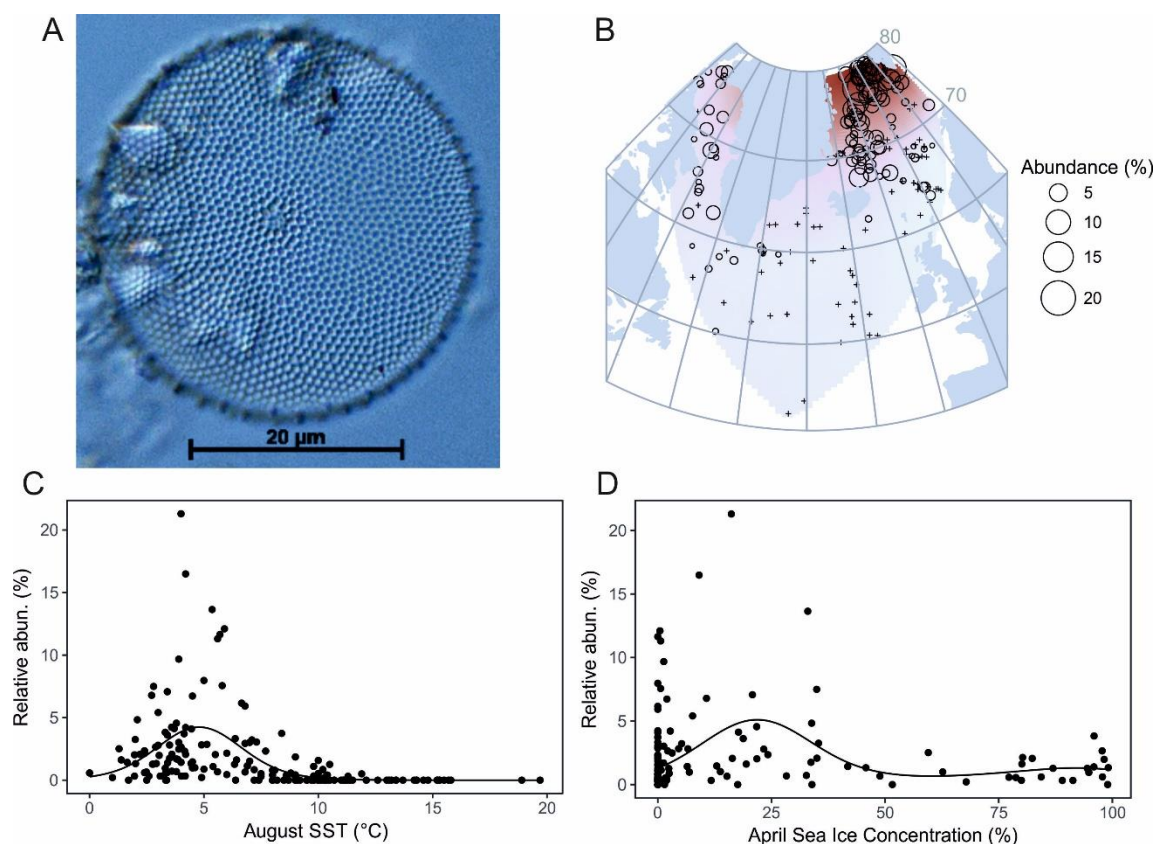
Synonym. *Thalassiosira tcherniai* Manguin.

References. Hasle and Syvertsen, 1996, p. 69, pl. 8; Cremer, 1998, p. 78, pl. 40, fig. 3; Bérard-Therriault et al., 1999, p. 24, pl. 7a, b, d-g; Scott and Thomas, 2005, p. 100, fig. 2.51; Pearce et al., 2014b, p. 452, figs. 57–58. Response to environmental gradients. Temperature range from 0 to 18.9°C, optimum 7.1°C (Fig. 19c). Statistically significant response to SST and sea ice. Although found at relatively high abundances (10–20%) at high sea ice concentrations (90–100%), the species is clearly more common at sea ice concentrations <50% (Fig. 19d).

Distribution. *Thalassiosira gravida* is very abundant in our dataset and was found in every sample, excluding two samples from the southern North Atlantic. Highest abundances (up to 60%) are found in Davis Strait/northern Labrador Sea.

Thalassiosira gravida is described in literature as a cosmopolitan species, typical for northern cold water to temperate regions (Hasle and Syvertsen, 1996; Jiang et al., 2001). *Thalassiosira gravida* is the main contributor to the East-West Greenland Current assemblage (Fig. 2) that dominates subarctic waters of the Labrador Sea (Andersen et al., 2004b) and the main component in the Norwegian-Arctic Waters mixing assemblage, which is most common between the Atlantic and the Arctic water masses (Koç Karpuz and Schrader, 1990). *Thalassiosira gravida* has been used as an indicator of higher water temperatures (Jiang et al., 2001; Witak et al., 2005), but also as a cold water indicator (Pearce et al., 2014a; Miller and Chapman, 2013). This confusion may be caused by misidentifications, or it has not been clarified whether the identified valves are vegetative cells or resting spores. *Thalassiosira gravida* does not form resting spores (Hasle and Syvertsen, 1996), and the *Thalassiosira gravida* spores mentioned in literature are likely resting spores of

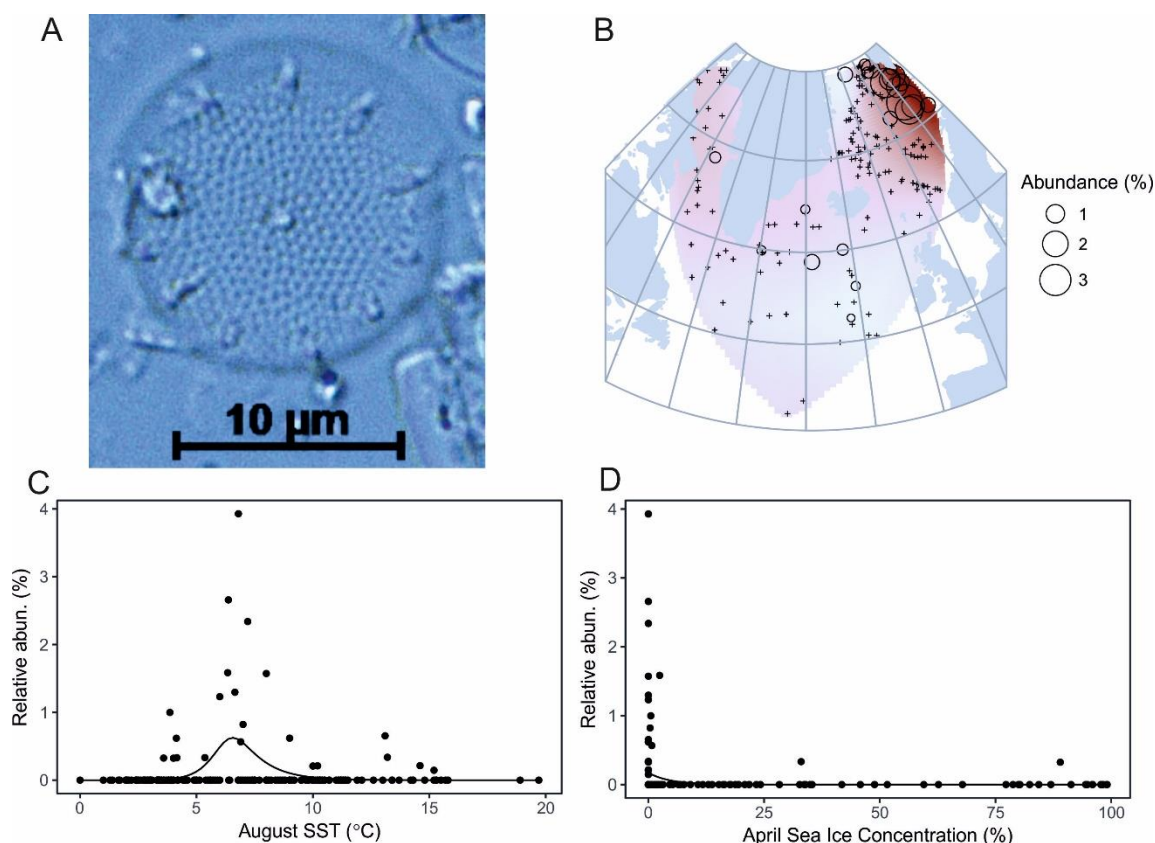
707 *Thalassiosira antarctica* var. *borealis*. While the former prefers higher water temperatures (between ca. 5
708 and 10°C), the latter is most abundant at SSTs at and below 5°C (Fig. 19c).
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713 Figure 20. *Thalassiosira hyalina*. a) Light microscopy image of the species (sample from Southeast Greenland, core
714 MD99-2322), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol +
715 refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.
716

717 *Thalassiosira hyalina* (Grunow) Gran (Fig. 20)
718 Basionym. *Coscinodiscus hyalinus* Grunow in Cleve & Grunow.
719 References. Sancetta, 1982, p. 242, pl. 5, figs. 4–5; Metzeltin and Witkowski, 1996, p. 120; Hasle and
720 Syvertsen, 1996, p. 69, pl. 8; Cremer, 1998, p. 78, pl. 40, figs. 1–2; Bérard-Therriault et al., 1999, p. 25, pl. 8a-
721 d; Pienitz et al., 2003, p. 16, pl. 3, fig. 4–5; Jensen, 2003, p. 122, pl. 9, figs. 3–5; Pearce et al., 2014b, p. 452,
722 figs. 59–60.
723 Response to environmental gradients. Temperature range from 0 to 11.9°C, optimum 4.7°C. Statistically
724 significant response to SST and sea ice (Fig. 20c, d).
725 Distribution. *Thalassiosira hyalina* mainly occurs at northern latitudes and the highest abundances in the
726 dataset (up to 20%) are found in Fram Strait, SW Svalbard, and the northern Nordic Seas.
727 *Thalassiosira hyalina* is described as an Arctic species and often associated with sea ice (Koç Karpuz and
728 Schrader, 1990; Krawczyk et al., 2010; 2013; Andersen et al., 2004b). It is an important species in the Sea
729 Ice/Marginal Ice Zone assemblage in Andersen et al. (2004b) (Fig. 2). *Thalassiosira hyalina* has been found to
730 be a common species in the Arctic Ocean spring bloom (von Quillfeldt, 2000). In Baffin Bay, it characterizes
731 the West Greenland Current assemblage described in Williams (1986), indicating relatively warm and saline
732 waters and low sea ice concentrations along the southwest coast of Greenland. Based on our dataset,

733 *Thalassiosira hyalina* is a cold-water species (most abundant at ca. 5°C) thriving at relatively low (ca. 20%)
 734 spring sea ice concentrations (Fig. 20b, c, d).



738
 739 Figure 21. *Thalassiosira nordenskiöldii*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170),
 740 b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location
 741 with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

742
 743 *Thalassiosira nordenskiöldii* Cleve (Fig. 21)

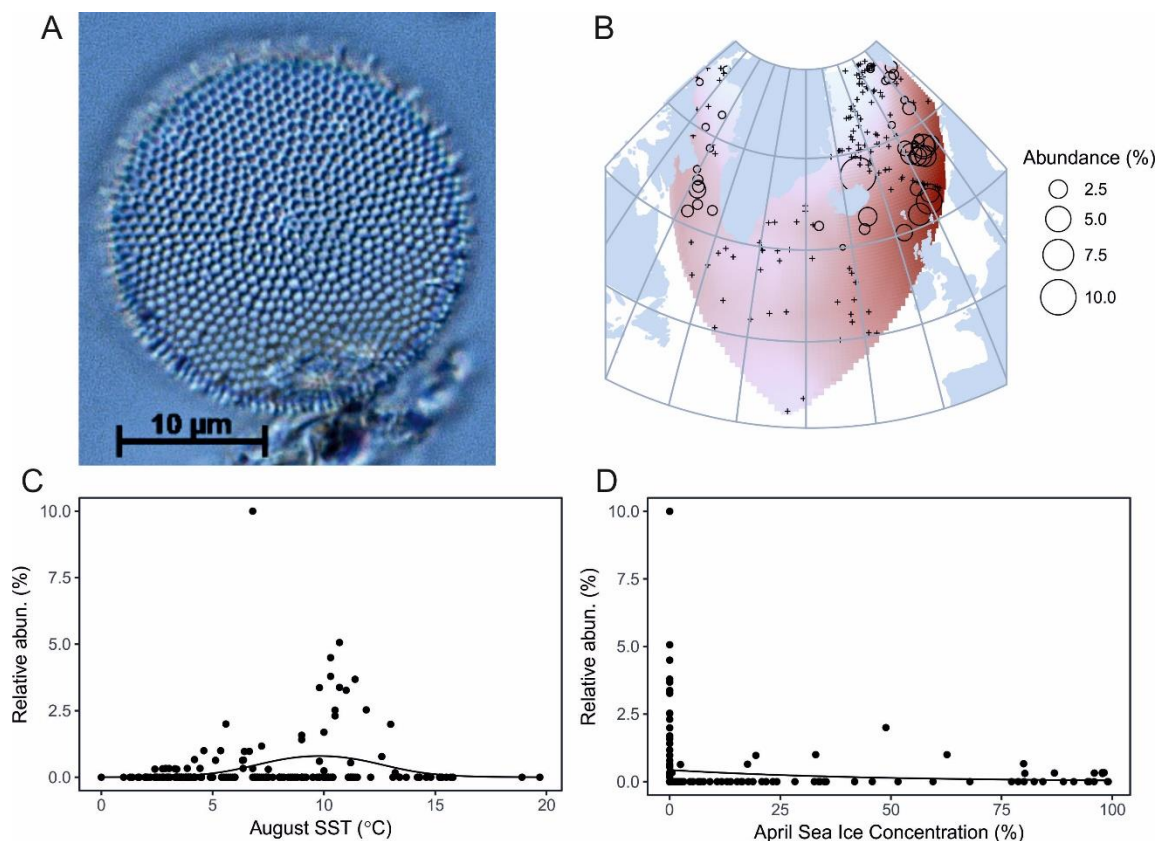
744 References. Sancetta, 1982, p. 243, pl. 5, figs. 8–9; Metzeltin and Witkowski, 1996, p. 118, 124; Hasle and
 745 Syvertsen, 1996, p. 56, pl. 5; Cremer, 1998, p. 79, pl. 39, figs. 2, 3; Bérard-Therriault et al., 1999, p. 26, pl. 8f,
 746 9a-f; Jensen, 2003, p. 123, pl. 10, figs. 5–8; Pienitz et al., 2003, p. 17, pl. 3, fig. 6; Pearce et al., 2014b, p. 453,
 747 figs. 63–65.

748 Response to environmental gradients. Temperature range from 1 to 13.2°C, optimum 7.1°C. Statistically
 749 significant relationship to SST and sea ice (Fig. 21c, d).

750 Distribution. Based on our dataset, *Thalassiosira nordenskiöldii* is relatively rare in the northern North
 751 Atlantic. Highest abundances (up to only 3 %) are found between northern Norway and SW Svalbard, but the
 752 species occurs also in individual samples from Baffin Bay and S and SW of Iceland (Fig. 21b).

753 *Thalassiosira nordenskiöldii* is described in literature as a neritic temperate-Arctic species blooming in the
 754 spring (Von Quillfeldt, 2000; Jensen et al., 2004 and references therein). It is an important contributor to the
 755 Sea Ice/Marginal Ice Zone assemblage in Andersen et al. (2004b) (Fig. 2) that reflects the winter Arctic sea
 756 ice limit. However, in these seasonally ice-covered areas it blooms after the pennate *Fragilariopsis* spp. and
 757 *Fossula arctica*, and is considered a late spring bloom species, reaching highest abundances after ice break
 758 up. *Thalassiosira nordenskiöldii* has further been suggested to be one of the most widely distributed cold

759 water diatom species in the North Atlantic and adjacent seas (Bérard-Therriault et al., 1999). The discrepancy
 760 between this statement and the distribution of *T. nordenskiöldii* in our dataset may stem from the fact that
 761 most of our sites are in the open ocean, whereas the species is associated with coastal (neritic) regions.



767
 768 Figure 22. *Thalassiosira pacifica*. a) Light microscopy image of the species (sample from Southeast Greenland, core
 769 MD99-2322), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol +
 770 refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

771
 772 *Thalassiosira pacifica* Gran & Angst (Fig. 22)
 773 References. Hasle and Syvertsen, 1996, p. 57, pl. 5; Bérard-Therriault et al., 1999, p. 27, pl. 8e, 10a-g; Pienitz
 774 et al., 2003, p. 18, pl. 4, figs. 1–6; Pearce et al., 2014b, p. 453, fig. 68.
 775 Response to environmental gradients. Temperature range from 2.4 to 13.2°C, optimum 9.0°C. Statistically
 776 significant relationship to SST and sea ice (Fig. 22c, d).
 777 Distribution. Most abundant in our dataset north of Iceland and in the Norwegian Sea (up to 10%), also found
 778 at low abundances in Baffin Bay and Davis Strait.
 779 *Thalassiosira pacifica* is described in literature as a cold- to temperate-water species restricted to the
 780 Northern hemisphere; it is most abundant along the coasts of the Pacific Ocean (von Quillfeldt, 2000; Jensen,
 781 2004). *Thalassiosira pacifica* could be defined as a temperate species more common in permanently ice-free
 782 regions.

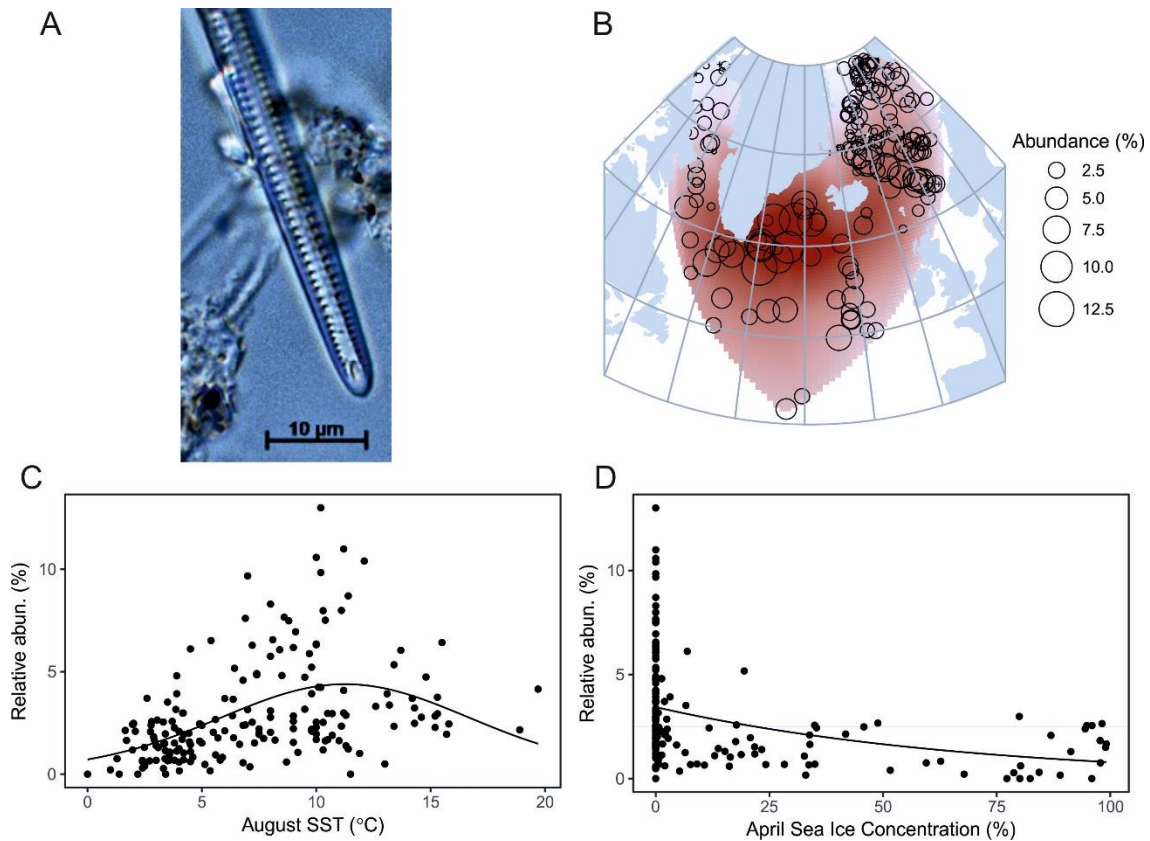


Figure 23. *Thalassiothrix longissima*. a) Light microscopy image of the species (sample from Baffin Bay, core SL-170), b) Geographical distribution (dark red shading indicates where abundances are highest, and symbol + refers to location with 0 abundances), c) Response to August SST, d) Response to April sea ice concentrations.

Thalassiothrix longissima (Cleve) Cleve & Grunow (Fig. 23)

Basionym. *Synedra thalassiothrix* Cleve

References. Sancetta, 1982, p. 245, pl. 6, figs. 3–4; Hasle and Syvertsen, 1996, p. 263, pl. 58 and 59; Cremer, 1998, p. 79; Bérard-Therriault et al., 1999, p. 58, pl. 48c, f; Jensen, 2003, p. 130, pl. 12, fig. 9; Pearce et al., 2014b, p. 453, figs. 69–70.

Response to environmental gradients. Temperature range from 1 to 19.7°C, optimum 8.6°C (Fig. 23c). Statistically significant relationship to both SST and sea ice. Relatively similar concentrations (3–4%) between 25 and 100% sea ice concentration, most abundant (ca. 10%) in ice-free areas (Fig. 23d).

Distribution. Very common species in the Northern Hemisphere found in almost every sample of the dataset. Highest abundances off SE Greenland, around Iceland and in the Nordic Seas.

Thalassiothrix longissima is described as a typical species in the Arctic/subarctic to northern temperate region (Hasle and Syvertsen, 1996). In the Labrador Sea, it has been used as an indicator of Atlantic Water inflow, because it is associated with the Irminger Current, the warm and saline component of the West Greenland Current (De Sève, 1999). In the Nordic Seas, it is abundant where Arctic and Atlantic water masses mix and contributes to the Arctic-Norwegian Waters Mixing Assemblage (Koç Karpuz and Schrader, 1990). On a North Atlantic scale, it belongs to the Sub-Arctic Waters assemblage (Fig. 2; Andersen et al. 2004b). *Thalassiothrix longissima* does not have a well-defined SST optimum but is most abundant around SSTs of 10°C (Fig. 23c).

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Concluding remarks

In this study, we presented the geographic distributions of diatom species frequently found in present-day and fossil diatom assemblages in the northern North Atlantic, and their responses to key environmental variables (SST and sea ice concentrations). The results will promote ecologically sound and harmonized use of diatoms as paleoclimate proxies in the region.

All species in the dataset have a statistically significant relationship with aSST. This is important as the dataset was originally developed for quantitative SST reconstructions (e.g., Oksman et al. 2017b). The most abundant taxa in the studied dataset are *Thalassiosira gravida*, *Thalassiosira antarctica* var. *borealis* resting spore and *Rhizosolenia hebetata* f. *semispina*, whereas the most common species (present in most surface samples) are *Thalassiosira gravida*, *Thalassiothrix longissima* and *Rhizosolenia hebetata* f. *semispina*. The results suggest that *Actinocyclus curvatulus*, *Bacteriosira bathyomphala* spore, *Fragilariopsis cylindrus*, *Fragilariopsis oceanica*, *Porosira glacialis*, *Rhizosolenia hebetata* f. *hebetata*, *Shionodiscus trifultus*, *Thalassiosira anguste-lineata*, *Thalassiosira antarctica* var. *borealis* resting spore, *Thalassiosira nordenskiöldii* and *Thalassiosira hyalina* are robust indicators of cold waters. *Coscinodiscus radiatus*, *Thalassionema nitzschioides* and *Shionodiscus oestrupii* are reliable indicators for warmer waters, and *Thalassiothrix longissima*, *Thalassiosira angulata*, *Thalassiosira gravida*, *Rhizosolenia hebetata* f. *semispina* and *Thalassiosira pacifica* indicate temperate waters.

The sea ice response models show a statistically significant relationship with sea ice for 15 species (Table 1). Some of these findings challenge previous ecological interpretations as species used as sea ice indicators, e.g., *Fragilariopsis cylindrus* and *Bacteriosira bathyomphala* spore (e.g., Krawczyk et al. 2010) did not show statistically significant relationships with sea ice over the large geographic coverage of our dataset, and thus their use as sea ice indicators should be carefully considered. The reliability of *Fragilariopsis cylindrus* as an indicator for sea ice has been previously discussed in von Quillfeldt (2004), where it was pointed out that *F. cylindrus* can also dominate phytoplankton blooms in areas never experiencing sea ice. According to von Quillfeldt (2004) its potential as a sea ice indicator seems to vary between regions, but the species is a very good indicator of cold water. Caution should be exercised with species such as *Rhizosolenia hebetata* f. *hebetata*, *Shionodiscus trifultus* and *Thalassiosira antarctica* var. *borealis* resting spore, as they are relatively abundant in seasonally ice-covered areas, but do not exhibit statistically significant relationships with sea ice concentrations, occurring abundantly also in ice-free conditions. The results imply that out of the 21 studied species, *Actinocyclus curvatulus*, *Fragilariopsis oceanica* and *Porosira glacialis* are the most robust sea ice indicators, as they have a statistically significant relationship with April sea ice concentrations and exhibit highest abundances at high sea ice concentrations. Reversely, species displaying a statistically significant relationship to sea ice occurring most abundantly at low (down to 0%) sea ice concentrations – *Coscinodiscus radiatus*, *Shionodiscus oestrupii*, *Thalassionema nitzschioides*, *Thalassiosira angulata* and *Thalassiosira pacifica* – hold the potential for being indicators of (near) ice-free conditions. *Rhizosolenia hebetata* f. *semispina*, *Thalassiothrix longissima*, *Thalassiosira anguste-lineata*, *Thalassiosira gravida*, and *Thalassiosira hyalina* all have a statistically significant relationship to sea ice, occurring most abundantly at relatively low sea ice concentrations.

855 This study highlights the importance of understanding the species-specific and region-specific ecologies of
856 diatoms used in paleoclimate reconstruction. It further identifies challenges that can be related to taxonomic
857 problems (here regarding *Thalassiosira antarctica* var. *borealis* resting spore). These types of identification
858 issues need to be resolved in the future as they can strongly affect ecological interpretations and may
859 ultimately lead to false climate reconstructions based on fossil diatom assemblages. The high-quality light
860 microscopy images and the assessment of main environmental preferences of North Atlantic diatom species
861 will promote harmonized species identification and sound ecological interpretation. This will aid
862 comparability and strengthen diatom-based reconstructions from the region.

865 Acknowledgements

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867 that improved this manuscript. M. Oksman acknowledges funding from the Finnish Graduate School in
868 Geology.

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- 1076 Appendix 1.

1077 Surface sediment sample locations, water depth (m), modern August SST (°C), modern April sea ice
 1078 concentration (%) and sampling year.

Sample	Latitude	Longitude	Water depth (m)	SST (°C)	Sea ice (%)	Sampling year
71-12	68°25.70'N	13°52.20'W	1633	5.5	0	pre-1990
71-17	70°00.39'N	13°01.09'W	1460	4.9	4.6	pre-1990
71-21	69°57.30'N	06°09.70'W	2612	7.7	0	pre-1990
71-26	67°20.10'N	02°09.90'E	1486	10.2	0	pre-1990
71-19	69°28.99'N	09°30.60'W	2210	7.2	0	pre-1990
71-20	70°04.20'N	06°52.69'W	2005	7.3	0	pre-1990
71-25	67°59.80'N	00°14.00'E	2850	9.5	0	pre-1990
71-22	69°20.10'N	03°37.09'W	1833	9.1	0	pre-1990
71-28	65°40.00'N	03°42.49'W	3140	8.6	0	pre-1990
57-14	66°59.80'N	06°12.30'W	3005	8.4	0	pre-1990
57-12	67°04.80'N	07°18.79'W	2093	8.0	0	pre-1990
57-10	67°00.30'N	09°18.49'W	1485	7.5	0	pre-1990
57-09	67°29.89'N	11°39.60'W	1662	6.8	0	pre-1990
57-08	68°10.30'N	11°32.40'W	1953	6.9	0	pre-1990
57-06	69°27.19'N	14°32.29'W	1458	4.5	6.9	pre-1990
57-05	69°08.29'N	13°07.20'W	1892	5.4	0	pre-1990
57-04	68°31.90'N	10°39.90'W	2122	7.0	0	pre-1990
52-03	62°12.00'N	00°00.00'E	705	10.7	0	pre-1990
52-04	61°21.40'N	03°21.40'W	1356	11.4	0	pre-1990
52-08	60°06.19'N	08°05.10'W	695	13.0	0	pre-1990
52-15	61°37.90'N	16°29.89'W	2355	12.6	0	pre-1990
52-19	62°52.69'N	15°09.30'W	1838	11.9	0	pre-1990
49A-07	62°56.59'N	01°02.10'E	1100	10.5	0	pre-1990
49A-11	63°59.29'N	01°16.99'W	2605	9.0	0	pre-1990
49A-41	63°04.30'N	03°20.30'E	900	11.3	0	pre-1990
49B-01	64°50.89'N	07°42.49'W	2683	7.4	0	pre-1990
49B-03	64°50.70'N	01°31.39'W	3004	9.5	0	pre-1990
49B-04	64°33.90'N	00°43.39'W	2798	9.7	0	pre-1990
49B-05	64°26.40'N	00°23.70'W	2702	9.8	0	pre-1990
49B-07	64°08.50'N	00°23.40'E	2500	9.8	0	pre-1990
49B-08	64°00.70'N	00°43.50'E	2403	10.0	0	pre-1990
49B-13	63°45.30'N	01°23.20'E	1900	10.0	0	pre-1990
49B-15	63°09.30'N	02°49.60'E	1002	11.1	0	pre-1990
49B-19	62°46.20'N	03°43.10'E	607	11.5	0	pre-1990
21291	78°00.40'N	08°04.00'E	2400	5.6	0.6	pre-1990
21292	77°59.80'N	07°25.00'E	3536	5.8	0.6	pre-1990
21293	77°59.80'N	06°40.50'E	2462	5.9	0.5	pre-1990
21294	78°00.19'N	05°21.90'E	2677	5.7	0	pre-1990
21295	77°59.80'N	02°27.80'E	3112	5.0	0	pre-1990
21296	78°00.10'N	00°37.50'E	3101	4.5	2	pre-1990
21297	77°59.80'N	01°02.80'W	3051	3.0	7.7	pre-1990
23239	67°29.80'N	08°21.50'E	1529	10.0	0	pre-1990
23054	67°39.40'N	05°47.80'E	1425	10.4	0	pre-1990
23055	68°25.20'N	04°00.30'E	2298	10.0	0	pre-1990
23056	68°30.10'N	03°30.30'E	2665	9.0	0	pre-1990
23059	70°18.40'N	03°06.40'W	2285	8.7	0	pre-1990
23065	68°30.00'N	00°49.90'E	2796	9.0	0	pre-1990
23069	67°39.90'N	01°35.30'E	1895	9.8	0	pre-1990

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1080 Appendix 1.

Sample	Latitude	Longitude	Water depth (m)	SST (°C)	Sea ice (%)	Sampling year
23071	67°05.10' N	02°54.30' E	1306	10.5	0	pre-1990
23072	67°00.10' N	03°51.10' E	1398	10.7	0	pre-1990
23074	66°40.20' N	04°54.80' E	1160	11.0	0	pre-1990
23327	67°48.30' N	06°01.20' E	1310	10.3	0	pre-1990
23334	68°40.39' N	05°56.10' E	3003	9.8	0	pre-1990
23335	67°40.39' N	05°49.90' E	1395	10.3	0	pre-1990
23337	70°03.19' N	00°03.50' E	3296	8.0	0	pre-1990
23338	72°35.70' N	10°29.50' W	2240	3.8	21.8	pre-1990
23341	70°57.00' N	05°32.59' W	1734	7.5	1.6	pre-1990
23342	71°37.80' N	08°24.79' W	1958	4.5	13.0	pre-1990
23343	72°12.79' N	12°59.70' W	2400	3.6	32.7	pre-1990
23345	71°40.09' N	14°19.00' W	1385	3.6	35.0	pre-1990
23346	71°17.50' N	14°03.90' W	1213	3.8	28.3	pre-1990
23347	70°26.20' N	16°04.80' W	1229	3.5	33.7	pre-1990
23348	70°25.09' N	18°56.89' W	729	1.0	67.8	pre-1990
23350	70°23.80' N	19°20.80' W	400	0.0	77.3	pre-1990
23351	70°21.70' N	18°12.30' W	1673	2.5	51.6	pre-1990
23352	70°00.40' N	12°25.39' W	1823	5.0	2.5	pre-1990
23353	70°34.20' N	12°43.39' W	1404	4.5	13.8	pre-1990
23354	70°19.80' N	10°37.69' W	1747	6.0	2.0	pre-1990
23359	65°31.69' N	04°08.80' W	2820	8.5	0.0	pre-1990
23295	71°08.10' N	05°59.20' W	1553	7.1	5.3	pre-1990
ArkV-147	74°13.80' N	10°02.29' W	3150	3.0	23.3	pre-1990
V30-103	52°46.00' N	36°34.99' W	3481	13.4	0	pre-1990
V30-177	54°04.00' N	24°10.99' W	3433	14.3	0	pre-1990
V30-110	57°22.00' N	39°12.00' W	3256	10.2	0	pre-1990
V30-128	64°04.90' N	30°13.00' W	2310	10.1	0	pre-1990
V30-130	67°30.00' N	15°04.00' W	858	6.8	0	pre-1990
V30-126	58°34.00' N	35°30.00' W	2456	11.4	0	pre-1990
V23-034	62°34.99' N	26°57.00' W	1414	11.2	0	pre-1990
V23-083	49°52.00' N	24°15.00' W	3871	15.5	0	pre-1990
RC9-228	52°32.89' N	18°45.40' W	3981	15.2	0	pre-1990
ArkVI-15-63	75°31.39' N	00°49.50' E	x	3.9	1.3	1990-2000
21845	69°27.60' N	15°45.70' W	x	4.2	16.4	1990-2000
21878	73°15.10' N	09°00.90' W	x	3.7	17.8	1990-2000
21892	73°43.99' N	09°37.50' W	x	3.4	18.8	1990-2000
21893	74°52.09' N	10°06.60' W	x	2.8	35.0	1990-2000
21895	75°24.79' N	07°18.60' W	x	3.4	20.8	1990-2000
21900	74°31.69' N	02°20.10' W	x	3.5	6.6	1990-2000
21901	75°56.59' N	03°44.40' W	x	4.0	6.5	1990-2000
21905	76°55.09' N	03°22.99' W	x	4.0	16.2	1990-2000
21906	76°50.50' N	02°09.00' W	x	4.2	9.1	1990-2000
21908	76°19.30' N	01°04.30' W	x	4.2	2.7	1990-2000
21909	76°06.30' N	01°00.30' W	x	4.0	2.2	1990-2000
21910	75°37.00' N	01°19.00' E	x	3.9	1.3	1990-2000
21911	75°03.49' N	02°58.50' E	x	3.8	1.3	1990-2000
21912	74°34.50' N	02°54.50' E	x	3.9	3.2	1990-2000
23254	73°03.30' N	09°44.60' E	x	6.8	0	1990-2000

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1083 Appendix 1.

Sample	Latitude	Longitude	Water depth (m)	SST (°C)	Sea ice (%)	Sampling year
23257	74°52.80'N	11°08.29' E	x	6.0	0	1990-2000
23258	74°59.80'N	13°57.49' E	x	7.0	0.4	1990-2000
23259	72°02.10'N	09°15.90' E	x	7.2	0	1990-2000
23260	72°08.20'N	11°27.10' E	x	8.0	0	1990-2000
23264	71°12.19'N	15°49.99' E	x	9.0	0	1990-2000
23269	71°26.29'N	00°39.80' E	x	7.5	0	1990-2000
23289	72°22.60'N	01°48.00' E	x	6.9	0.7	1990-2000
23297	70°00.70'N	00°04.80' E	x	8.0	0	1990-2000
HU91-45-18	55°02.59'N	52°07.80' W	x	8.2	1.5	1990-2000
HU91-45-28	56°36.90'N	49°45.00' W	x	8.8	0	1990-2000
HU91-45-51	59°29.59'N	39°18.40' W	x	10.4	0	1990-2000
HU91-45-56	59°38.10'N	36°07.50' W	x	11.3	0	1990-2000
HU91-45-60	59°50.89'N	33°34.90' W	x	12.1	0	1990-2000
HU91-45-71	58°56.40'N	28°44.40' W	x	13.1	0	1990-2000
HU91-45-80	53°03.40'N	33°31.80' W	x	13.7	0	1990-2000
HU91-45-90	53°19.80'N	45°15.60' W	x	11.2	0	1990-2000
HU91-45-93	50°12.30'N	45°41.20' W	x	9.0	0	1990-2000
SU90-I-03	51°52.69'N	39°46.80' W	x	13.4	0	1990-2000
SU90-I-04	58°12.60'N	45°12.30' W	x	8.1	0	1990-2000
SU90-I-06	59°31.50'N	39°27.10' W	x	10.3	0	1990-2000
SU90-I-08	60°03.49'N	22°00.49' W	x	13.2	0	1990-2000
SU90-I-09	55°57.00'N	20°19.00' W	x	14.6	0	1990-2000
SU90-I-10	52°34.00'N	21°55.99' W	x	15.2	0	1990-2000
SU90-06	42°01.80'N	32°42.70' W	x	19.7	0	1990-2000
SU90-08	43°31.20'N	30°24.49' W	x	18.9	0	1990-2000
SU90-20	59°51.70'N	39°39.79' W	x	10.2	0	1990-2000
SU-90-21	60°17.10'N	40°13.09' W	x	10.0	0	1990-2000
SU90-22	62°32.50'N	38°49.99' W	x	9.2	0	1990-2000
SU90-25	62°54.60'N	32°10.80' W	x	11.2	0	1990-2000
SU90-27	62°35.89'N	28°21.40' W	x	11.1	0	1990-2000
SU90-30	64°39.90'N	30°10.60' W	x	10.0	0	1990-2000
SU90-34	57°33.10'N	21°09.60' W	x	14.2	0	1990-2000
SU90-35	57°34.20'N	20°50.20' W	x	14.3	0	1990-2000
SU90-38	54°05.40'N	21°04.90' W	x	14.8	0	1990-2000
SU90-40	51°43.09'N	21°52.69' W	x	15.3	0	1990-2000
SU90-41	51°43.30'N	21°52.39' W	x	15.3	0	1990-2000
SU90-43	50°17.29'N	19°17.89' W	x	15.7	0	1990-2000
SU90-44	50°06.19'N	17°54.60' W	x	15.8	0	1990-2000
HU90-13-11	58°54.90'N	47°05.10' W	x	7.4	0	1990-2000
HU90-13-17	58°12.49'N	48°21.60' W	x	8.0	0	1990-2000
HU90-13-20	58°21.60'N	54°27.40' W	x	4.9	0.7	1990-2000
JM06-WP-19-MC	78°00.77'N	02°30.17' W	2859	2.0	21.8	2006
JM06-WP-21-MC	77°00.20'N	03°23.66' W	1779	2.5	15.2	2006
JM06-WP-24-MC	74°37.99'N	11°11.20' W	2974	1.7	33.9	2006
JM06-WP-26-MC	74°53.49'N	10°46.09' W	3064	2.0	45.8	2006
JM06-WP-07-BC	78°52.62'N	07°20.45' W	1181	4.1	0	2006
JM06-WP-12-BC	78°54.46'N	02°24.91' E	2426	2.7	10.7	2006
JM06-WP-10-BC	78°56.17'N	05°24.07' E	2483	3.6	0	2006

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1086 Appendix 1.

Sample	Latitude	Longitude	Water depth (m)	SST (°C)	Sea ice (%)	Sampling year
JM06-WP-16-MC	78°53.76' N	00°16.91' E	2546	2.1	33.8	2006
JM06-WP-14-BC	78°55.88' N	01°06.46' E	2502	2.4	24.2	2006
JM07-WP-182-MC	77°30.54' N	00°02.26' W	3100	2.6	1.9	2007
JM07-WP-180-MC	77°28.60' N	02°02.53' W	3029	2.0	11.8	2007
JM07-WP-176-MC	69°51.58' N	22°07.90' W	482	1.4	80.1	2007
JM07-WP-170-MC	73°44.87' N	14°11.95' W	2285	1.3	59.5	2007
JM07-WP-171-MC	73°46.13' N	13°00.60' W	2570	1.6	41.8	2007
JM07-WP-172-MC	73°47.08' N	12°21.64' W	2742	2.0	35.4	2007
JM08-WP-337-MC	78°08.13' N	08°30.41' E	1733	4.5	0	2008
JM08-WP-338-MC	78°10.02' N	06°32.73' E	1766	3.9	0.5	2008
JM08-WP-339-MC	77°59.73' N	05°58.35' E	2343	4.4	0.3	2008
JM08-WP-341-MC	77°59.71' N	04°07.44' E	2952	4.2	0	2008
JM08-WP-344-MC	75°58.93' N	08°19.38' E	2288	6.4	0	2008
JM08-WP-345-MC	75°59.68' N	11°00.10' E	2184	6.6	0	2008
JM08-WP-348-MC	75°59.73' N	13°17.89' E	1264	6.3	2.4	2008
JM08-WP-350-MC	76°47.88' N	01°458.80' E	245	5.4	33	2008
HU2008-029-002	61°27.82' N	58°02.15' W	2668	6.4	19.5	2008
HU2008-029-006	64°23.58' N	58°08.08' W	857	4.6	62.7	2008
HU2008-029-010	68°39.99' N	59°59.99' W	1479	3.3	96	2008
HU2008-029-014	70°27.70' N	64°39.44' W	2060	2.9	97.8	2008
HU2008-029-019	75°28.12' N	70°38.07' W	602	2.8	94.5	2008
HU2008-029-028	76°58.73' N	71°53.43' W	1048	2.4	80.3	2008
HU2008-029-032	76°19.72' N	71°25.26' W	696	2.4	84.3	2008
HU2008-029-036	76°34.38' N	73°57.32' W	680	2.2	82.4	2008
HU2008-029-040	75°34.76' N	78°37.77' W	580	3.3	78.8	2008
HU2008-029-047	74°01.39' N	77°06.97' W	870	3.4	97.8	2008
HU2008-029-055	74°05.52' N	78°43.11' W	866	3.4	95.9	2008
HU2008-029-063	72°24.38' N	67°43.00' W	2375	2.9	99.1	2008
HU2008-029-068	68°13.68' N	57°37.08' W	437	4.0	89	2008
KG2	65°59.97' N	60°29.97' W	393	2.8	86.9	2008
MC688	62°32.58' N	52°37.92' W	2634	5.1	0	2008
MC690	68°58.12' N	59°34.38' W	1339	3.3	94.8	2008
MC691	72°30.37' N	61°57.34' W	1215	3.0	98.2	2008
MC692	71°25.53' N	70°26.40' W	798	3.4	99	2008
MC693	68°50.29' N	66°16.26' W	865	3.1	91.3	2008
MC694	68°31.87' N	68°19.83' W	1550	3.3	0	2008
MC695	64°59.98' N	59°00.03' W	467	4.2	80	2008
MC696	64°38.40' N	57°59.95' W	1009	5.6	48.9	2008
MC697	62°33.16' N	56°28.08' W	2329,5	6.4	17.6	2008